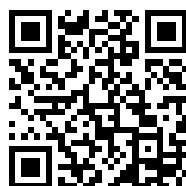

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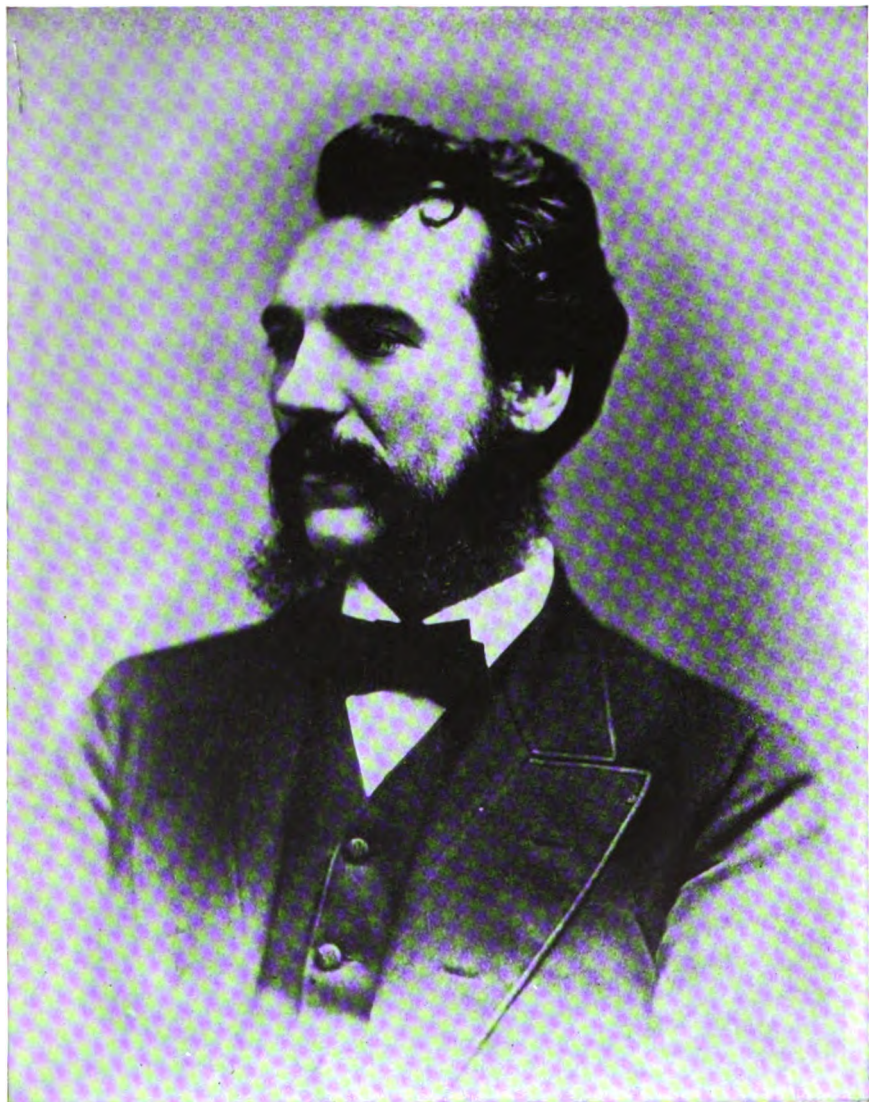
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BEGINNINGS OF TELEPHONY



ALEXANDER GRAHAM BELL

From a photograph taken in 1876, the year in which the telephone was patented.



BEGINNINGS OF TELEPHONY

BY
FREDERICK LELAND RHODES

WITH A FOREWORD BY
GENERAL JOHN J. CARTY
VICE-PRESIDENT OF THE AMERICAN
TELEPHONE AND TELEGRAPH COMPANY



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First Edition

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TO MY WIFE

E. C. R.

WITHOUT WHOSE ENCOURAGEMENT
THIS BOOK WOULD NOT HAVE BEEN
WRITTEN

"We scientific workers are perhaps too neglectful of our past history for the obvious reason that our present is so engrossing."

H. H. TURNER
*Savilian Professor of Astronomy
Oxford University*

FOREWORD

THE extension of the spoken word by means of electrical systems of intercommunication represents a unique and revolutionary step in man's progress. Among the great inventors of all time, Alexander Graham Bell must hold a foremost place, for it was he who invented the electrical speaking telephone. He was the first to discover the principle by which the electrical transmission of speech could be accomplished, and it was he who devised the apparatus by means of which this marvel was for the first time performed.

To his successors in the telephone art he gave the principle on which the telephone operates, and the instruments with which he had demonstrated its correctness. From that beginning have come the great telephone systems of today with their millions of stations and with means for connecting, for purposes of conversation, even those on different continents. The telephone has now become an indispensable element in the life of the social organism. This marvelous development, with all of its potentialities for promoting economic and social progress, has come about in a little over fifty years.

While Bell stated and demonstrated the fundamental principle with astonishing completeness, the difficulties which faced the pioneers who sought to make it commercially useful seemed almost insurmountable. All that was known of telephone engineering was represented in the crude and elementary first telephone of Bell. Only the inventor and his assistant, Thomas A. Watson, understood even the rudimentary technique of speech transmission. Difficulties were encountered by all who attempted to construct a telephone system, and there were no precedents to follow in overcoming these difficulties. All improvements had to be worked out from fundamentals, but the fundamentals themselves were little understood even by the most learned. Great credit is due to those who, by research, invention, and development, created a new public service from the beginnings of the telephone art.

As is the case with the first efforts in every new field, the difficulties and triumphs of the early workers are likely to become lost in a mist of tradition and conflicting statements. The author, a member

of the distinguished group of scientists and engineers who have continued and extended the work of Alexander Graham Bell, has in this book performed a service of permanent value in collecting from original sources and classifying the facts relating to the early history of the telephone, and in presenting them in interesting form.

This volume should be of especial interest to inventors, lawyers, and students of our patent system, for in no other publication is to be found the history of the great legal controversies which raged about the invention of the telephone. Never before had the claims of an inventor been subjected to such exhaustive litigation and judicial scrutiny, and never before did an inventor receive such a complete and dramatic vindication. In compact and readable form, the author has given in this volume the essentials of court decisions in that remarkable group of telephone cases which were characterized by Mr. Justice Brewer as the most important and the most protracted litigation which had arisen under the patent system in this country. The value of the book is greatly enhanced by copious references to original and authentic sources, the existence of which would otherwise be difficult to discover.

The word "telephone" as applied to devices of various kinds was in use long before the invention of Bell. An appendix contains a discussion of these devices, illustrated by numerous quotations. These, together with a list of references, furnish the best guide to the history of this word anywhere to be found.

This book will serve as an inspiration to the thousands of telephone workers in their efforts to carry on and extend the work of the pioneers; and as a chronicle of the beginnings of a great art and of a remarkable phase of human accomplishment, it deserves to be read by that growing section of the public which has become so much interested in scientific progress and achievement.

JOHN J. CARTY.

PREFACE

THE purpose of this book is to afford present-day workers in the field of telephony, and students of the history of electrical communication, an opportunity to become familiar with some of the problems that vexed the pioneers in the telephonic art. The writer, having had the opportunity of familiarizing himself to some extent with the early accomplishments in telephony, has undertaken in this book to make the information that he has collected available to others interested in the subject. Wherever possible, original sources of information have been consulted. A list of these sources is contained in an appendix and references to them are made in the text.

With a few exceptions, the aim has been to carry each chapter only so far as to bring the portion of the art, discussed in it, to what might be termed its "middle period." It should be appreciated that many improvements have subsequently been made to bring telephony to its present state. An adequate description of the later work on almost any one of these subjects, covering the ground from where it is left in this book to the present day, would, in itself, require a volume of no inconsiderable size. There are also many branches of the telephonic art which have not been touched upon in this volume.

The writer is indebted to many of his associates for their kindly aid, not only in furnishing data and references, but also in verifying the accuracy of his work. His grateful acknowledgment is due to Mr. Roger Bartlett Hill for assistance in preparing the appendices and notes, and for carefully collating the text and the illustrations; and also to Bell Telephone Laboratories for photographs furnished from the Bell System Historical Museum.

F. L. R.

Short Hills, New Jersey.
April, 1929.

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BEGINNINGS OF TELEPHONY

CHAPTER I

ALEXANDER GRAHAM BELL: HIS EARLY LIFE AND THE GERMINATION OF HIS TELEPHONE INVENTION

RARELY has a man been better equipped, by inheritance, training, and experience, for solving a particular problem than was Bell when he invented the electric speaking telephone. The qualifications which he brought to the task and the sequence of events leading up to the invention will be apparent in the condensed account of his early life and researches which follows. He was of the third generation in a family of expert teachers of articulation. His grandfather, Alexander Bell,¹ had invented a system for the correction of stammering and similar defects of speaking. His father, Alexander Melville Bell,² born in Edinburgh, Scotland, was the inventor of a system of "visible speech," the author of textbooks on the art of speaking, and a distinguished teacher of elocution at the university of his native city.

Alexander Graham Bell was born in Edinburgh, Scotland, March 3, 1847. He received his early education at McLarens Academy and the Royal High School in Edinburgh; attended lectures on classical subjects at Edinburgh University for one year; took a course in anatomy at University College, London, and matriculated as an undergraduate of the London University.³ He also received, at a very early age, training in music from Signor Auguste Benoit Bertini and, after Bertini's death, his musical education was carried on by his own mother, following the Bertini method.⁴

Alexander Graham Bell was the second of three sons, all of whom from early childhood had their attention directed to acoustics and particularly to the subject of speech. Their father urged them to study

¹ Nelson's *Encyclopedia*; Bell, Alexander Melville.

² Ref. (1).

³ Ref. (1); Ref. (2), pp. 6, 7.

⁴ Ref. (2), p. 7.

everything relating to these matters and encouraged them to experiment. In response to his offer of a prize for the construction of a successful speaking machine,⁵ Alexander Graham Bell and his brother Melville made one which was capable of articulating a few words. This speaking contrivance was a direct imitation of the vocal organs themselves. It was modeled in gutta-percha from a human skull. The soft parts of the mouth were filled in with india-rubber, stuffed with cotton batting. Upon blowing a current of air through the artificial larynx, a voice-like sound was produced and, upon operating the artificial lips and tongue, a number of words were distinctly pronounced.

Alexander Graham Bell's older and younger brothers readily took up elocution as their profession, but it was not until his younger brother died and his father appealed to him to come to London and be his assistant, that Alexander Graham definitely adopted his father's profession.

At the age of seventeen or eighteen, he accepted a position as teacher of music in Weston-House Academy, Elgin, Morayshire, and while there he made experiments⁶ using his mouth to determine the resonance pitches of the mouth cavities during the production of vowel sounds. At the time, Bell believed that these experiments were original with himself,⁷ and he communicated the results to Mr. A. J. Ellis, of London, a leader in philological circles and the man who made the English translation, published in 1875, of Helmholtz's classic work, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*. From Ellis, Bell learned that his experiments had already been made by Helmholtz, who had demonstrated the compound nature of the vowel sounds by producing them artificially by a synthetical process. Ellis attempted to describe to Bell the apparatus used by Helmholtz, consisting of resonators and tuning forks of different pitches, kept in simultaneous vibration by means of electromagnets; but, as Bell himself said,⁸ years later, he found that, at that time, he did not have sufficient electrical knowledge to understand the arrangement used by Helmholtz. He thereupon determined to study electricity, for he felt that it was his duty, as a student of speech, to acquaint himself with the researches of Helmholtz and to repeat Helmholtz's experiments.

⁵ Ref. (2), pp. 7, 208.

⁶ Ref. (2), pp. 7, 8, 209, *et seq.*

⁷ Ref. (2), pp. 8, 9.

⁸ Ref. (2), pp. 8, 9.

Pursuant to this determination, the year 1867 found Bell, then an instructor⁹ in Somersetshire College, Bath, England, experimenting with ordinary telegraph apparatus and vainly striving to cause the continuous vibration of a tuning fork by means of electromagnets.

Owing to the death of his eldest and youngest sons by tuberculosis, and the fear that his only remaining son might fall a victim, Bell's father resigned his lectureships, disposed of his practice in London, and decided to emigrate to Canada.¹⁰ The family landed at Quebec in August, 1870,¹¹ and soon settled at Tutelo Heights, near Brantford, in Ontario, Canada, where Bell lived until late in 1872, except for occasional visits to the United States. He was invited by the Board of Education of the City of Boston, Massachusetts,¹² to make experiments in the city school for deaf mutes, in order to ascertain whether these afflicted children could be taught to speak by means of his father's system of "visible speech." In response to this invitation, Bell went to Boston in April, 1871, where he remained about two months experimenting at the city school for the deaf and dumb. Subsequently he visited the Clarke Institution for Deaf-Mutes¹³ in Northampton, Massachusetts, and the American Asylum for Deaf-Mutes in Hartford, Connecticut, remaining about two months at each of these places. He also sojourned for a few months at Newton Lower Falls, Massachusetts, where he received some private pupils who were deaf. On October 1, 1872, he took permanent residence in the United States, living first at 35 West Newton Street, Boston, where he opened a school of vocal physiology,¹⁴ receiving as pupils, deaf mutes, persons with hearing but of defective speech, and teachers of the deaf and dumb.

Becoming much interested in the subject of the general education of the deaf and dumb, Bell undertook complete charge of the education of George Sanders,¹⁵ a very young deaf child who was sent by his parents to live in the same boarding place where Bell resided. A teacher was employed by Bell to carry on George Sanders's general education under Bell's direction.

⁹ Ref. (1).

¹⁰ Ref. (1).

¹¹ Ref. (2), p. 9.

¹² Ref. (2), p. 10.

¹³ Ref. (2), p. 10.

¹⁴ Ref. (2), p. 11.

¹⁵ Ref. (2), p. 11.

A year later, in October, 1873, Bell removed to Salem, Massachusetts, where he lived in the house of Mrs. George T. Sanders, the grandmother of his young pupil. Meanwhile having been appointed professor of vocal physiology¹⁶ in the School of Oratory of Boston University, he carried on his professional work at 18 Beacon Street, Boston, in rooms connected with Boston University.

Before coming to reside permanently in the United States, Bell had conceived the idea¹⁷ of a system of harmonic multiple telegraphy, in which a number of telegraphic signals could be sent simultaneously over the same circuit in either or both directions. After settling in Boston, he continued his experiments in multiple telegraphy. His knowledge of Helmholtz's apparatus for the artificial production of vowel sounds led him to make experiments of a similar character, and these gave rise in his mind to his multiple telegraph inventions.

At first he used tuning forks for his transmitting and receiving instruments.¹⁸ Each tuning fork had its prongs placed between the poles of an electromagnet and each transmitting fork was so arranged, with a connecting wire dipping into a cup of mercury, that current from an electric battery caused the fork to vibrate continuously at its normal period or pitch, emitting its characteristic musical tone. The electrical circuit, of which the fork formed a part, was made and broken at each vibration. By the operation of a telegraph key in the circuit of each fork, the intermittent current, controlled by the vibration of that particular fork, could be sent out over a telegraph line wire and interrupted at will. Each one of the transmitting tuning forks could thus be made a telegraphic sender.

At the receiving end of the line was a similar set of tuning forks, each one tuned to the same pitch as one of the transmitting forks. These receiving forks were provided with electromagnets, by which they could be set in vibration, and the current incoming from the line passed through the coils of the electromagnets of all of the receiving forks. There was thus provided a number of pairs of tuning forks, each pair consisting of a transmitting fork at one end of the line and a receiving fork of identical pitch at the other. With this arrangement, the intermittent current controlled by a particular transmitting fork would cause the forcible vibration of one receiving fork and one only—

¹⁶ Ref. (1).

¹⁷ Ref. (2), p. 12, *et seq.*

¹⁸ Ref. (2), p. 13, *et seq.*

namely, the one that was in unison with that particular transmitting fork. This one receiving fork would continuously emit its fundamental note all the time that the key associated with its corresponding fork at the transmitting end was depressed, and would stop the moment that key was raised and the circuit opened. The pitches were so selected that no transmitting fork should be able to cause vigorous vibration in the prongs of any receiving fork of different pitch from its own. By operating the key connected to any one of the transmitting forks in the manner of a telegraph-sending key, long or short musical tones, the equivalent of dashes or dots, would be emitted by that particular receiving fork which had the same pitch as the transmitting fork employed, but none of the other receiving forks would be thrown into vigorous vibration. If two or more keys should be depressed simultaneously, then two or more receiving forks, corresponding in pitch to the transmitting forks employed, would be set into vigorous vibration, each responding to the signals sent from one, and one only, of the transmitting forks. Thus two or more telegraphic messages could be sent simultaneously along a single line wire and received separately by distinct receiving instruments.¹⁹

The reader already familiar with modern telegraph and telephone practice will recognize, in this early invention, the prototype of the electric wave filter and the germ of the "carrier" method of signaling.

During the winter of 1873-1874, Bell extended his multiple telegraph experiments.²⁰ For the tuning forks at the receiving end he substituted tuned reeds, each consisting of a flat plate or blade of steel clamped rigidly to the top of a post or standard extending up from a baseboard and with the free end extending horizontally over the poles of a double-pole electromagnet, mounted vertically on the same base with the post mentioned above. This arrangement was subsequently modified by providing the steel reed with a tuning apparatus, and using a single-pole electromagnet with an adjusting device whereby its distance from the free end of the steel reed could be varied and regulated.

While experimenting with these instruments at Salem during the winter of 1873-1874, Bell discovered ²¹ that the reed of one of them could be forced to give out a sound of different pitch from that of the tone produced by its normally free vibration. Thereafter, it became

¹⁹ Ref. (2), p. 15.

²⁰ Ref. (2), p. 15.

²¹ Ref. (2), p. 16.

his habit to tune his telegraphic receivers by pressing the reed firmly against his ear while the transmitting instrument was in operation and, plucking the reed with his finger, noticing the pitch of the sound produced by its free vibration. If the sound of the reed when its vibrations were damped by contact with his external ear was higher or lower in tone than the normal pitch of the reed, he raised or lowered the normal pitch by shortening or lengthening the free portion of the reed; his object in either case being to bring the free period of the reed into unison with the vibrations of the transmitting instrument.²²

About December, 1873,²³ the idea occurred to Bell of improving the operation of his harmonic telegraph by causing the transmitting interrupters each to make and break the primary circuit of an induction coil, the secondary circuit of which could be placed in the main line by the depression of a key. Previously, the interrupters had been so connected as to make and break the main line itself, but that arrangement had not permitted of uninterrupted earth connection at either end of the circuit.

While the use of induction coils overcame this difficulty, they introduced another which had not hitherto presented itself to him. With induction coils, each make and break of the primary circuit produced a momentary electrical impulse in the secondary circuit. Thus there were transmitted over the line twice as many electrical impulses as there were complete vibrations of the transmitting instrument, so that the ordinary electromagnet of the receiving instrument would attract its reed armature twice as many times per second as it would had it been placed in the primary circuit. Fearing that, under these circumstances, the transmitting reed would be unable to cause the vibration of a receiving reed of its own pitch, but would require the receiving reed to be an octave above the pitch of the transmitting reed, Bell was led to consider the subject more closely. Recognizing the fact that the alternate impulses in the secondary circuit were of opposite kind, he saw that the polarity of the electromagnets of the receiving instruments would be reversed at every impulse, and it occurred to him that, if the reed armature of a receiving instrument should be permanently magnetized, it would be alternately attracted and repelled by its electromagnet. In order to render the reeds of the receiving instruments per-

²² Ref. (2), p. 16.

²³ Ref. (2), p. 18, *et seq.*

manently magnetized,²⁴ he thought of attaching them to the poles of a permanent magnet and allowing the free ends of the reeds to be attracted and repelled by the poles of an electromagnet. Thereupon a new difficulty presented itself. Unless the attracting and repelling impulses of the electromagnet were properly timed to the normal vibrations of its reed armature, they would tend to retard the motion of the latter. In other words, in order that the receiving reed should be thrown into full and vigorous vibration, it appeared to be necessary that the attracting and repelling impulses should come at equal distances apart so that the reed of the receiving instrument should be attracted only while it was normally moving toward the electromagnet and repelled only while it was normally moving away. It became evident to him, in considering the action of the transmitting reeds in making and breaking the primary circuit, that the alternate positive and negative impulses induced in the secondary circuit would not come at equal intervals apart unless the primary circuit were to be closed for exactly the same length of time that it remained open. As he felt it to be extremely problematical whether any of his transmitting, circuit-breaking reeds could fulfill this condition, he began to consider what changes could be made in the transmitting instruments that would enable them to do it. [It then occurred to him that a permanently magnetized reed, if caused to vibrate by mechanical means, could itself occasion electrical impulses in the coils of its electromagnet of the kind required, for he was aware of the fact that when a permanent magnet is moved toward the pole of an electromagnet, a current of electricity is generated in the coil of the electromagnet, and that, when the permanent magnet is moved from the electromagnet, a current of opposite kind is induced in the coil of the latter.] He had no doubt, therefore, that a permanent magnet, like the reed of one of his receiving instruments, vibrating with the frequency of a musical sound in front of the pole of an electromagnet, would induce, in the coil of the latter, alternating positive and negative impulses, corresponding in frequency to the vibrations of the reed, and that these reversed impulses would come at equal distances apart. He planned to set his transmitting reeds in vibration by directing a current of air upon them as was done in the case of organ reeds. The simplicity of his idea fascinated him, as it did away with batteries, current interrupters, and induction coils. But again

²⁴ Ref. (2), pp. 20, 21.

new difficulties loomed. It seemed extremely doubtful²⁵ whether a current generated by the vibration of a magnetized reed in front of an electromagnet would be sufficiently powerful, to produce, at the receiving end of a circuit, a vibration sufficiently intense to be utilized practically on real lines, for purposes of multiple telegraphy. So, instead of pursuing the idea further at that time, he hit upon a plan²⁶ of using a rotating circuit-breaking cylinder to put current alternately on and off the line at intervals equal in duration and sufficiently rapid to create a succession of intermittences of current at a rate corresponding to the number of vibrations executed by the free reed of the receiving instrument in producing its normal musical tone.

At this same time (the winter of 1873-1874) Bell became familiar with two remarkable scientific instruments²⁷ which captivated his interest as he saw possibilities of utilizing them in his professional work of teaching speech to children who were deaf.

One of these was the so-called "manometric capsule" of Koenig.²⁸ It consisted of a cavity in a piece of wood, divided into two portions by a partition, or diaphragm, of gold-beater's skin. To one compartment was connected a gas pipe, so that it could be filled with gas, which was lighted at a burner let into one side of the capsule. The other compartment was connected with a speaking-tube. Whenever a noise was made in the tube, the vibrations of the air were communicated, through the membrane, to the gas, and thence to the flame. When vocal sounds were uttered in the tube, the flame moved up and down just as many hundred times per second as the voice vibrated. On looking at the reflection of the flame in a rapidly revolving mirror, a new aspect was produced with every change of sound. For example, the vowel $\bar{e}$ presented the appearance of a long band of light with teeth like a saw. When the sound was changed to $\bar{i}$ (as in "it"), each tooth of the saw became notched. The vowel $\bar{e}$ (as in "bed") caused the appearance of a pleasing and complicated pattern, resembling a piece of Brussels lace. Every sound had its own distinct image in the mirror.

The other instrument, called the "phonautograph,"²⁹ * consisted of

²⁵ Ref. (2), p. 20.

²⁶ Ref. (2), p. 22.

²⁷ Ref. (2), p. 23.

²⁸ Ref. (2), p. 23, *et seq.*

²⁹ Ref. (2), pp. 23 to 28.

* Originally devised by Léon Scott; improved by Morey.

a speaking-trumpet closed at one end by a stretched membrane to which was attached a light wooden lever bearing a stylus, actually a bristle, at its far end. The point of the bristle just touched a plate of smoked glass which, by suitable mechanism, could be moved at a uniform rate of speed in a direction at right angles to the direction of vibration of the bristle when the latter was put in motion by the voice speaking into the cone of the trumpet. The point of the bristle scraped off the lamp black wherever it touched, thus tracing a sinuous line that changed its shape corresponding to the sound uttered. These instruments will be recognized as early mechanical precursors of the modern oscillograph which photographs the shapes of electrical speech waves.

Bell exhibited these two instruments in the course of an address³⁰ which he delivered in June, 1874, before a convention of teachers of articulation to the deaf and dumb, which met at Worcester, Massachusetts, suggesting that deaf-mutes, by uttering sounds into these instruments and observing their appearance, could tell at once whether they were producing the correct sounds. He was struck by the similarity between the mechanism of the phonautograph and that of the human ear,³¹ and had the thought that, if the instrument could be remodeled after the pattern of the ear, it might produce more accurate tracings of speech vibrations. To obtain more precise information concerning the structure of the human ear, he consulted Dr. Clarence J. Blake of Boston, a distinguished aurist. Dr. Blake became interested and suggested to Bell that instead of trying to make a phonautograph modeled after the pattern of the human ear, he should attempt to use a human ear itself, taken from a dead subject.³² Dr. Blake prepared a specimen for Bell who used it successfully in making tracings of sound vibrations on smoked glass. He carried this apparatus with him from Salem to Brantford in July, 1874, and continued making experiments with it during his summer vacation.³³ In the course of that summer, in connection with his work on the harmonic telegraph, using reeds instead of tuning forks, he came to realize that the mechanical vibration of a transmitting reed³⁴ would produce on the line wire an undulatory current of electricity corresponding to the undulatory motion of the reed. That is, the direction or polarity of the

³⁰ Ref. (2), p. 27.

³¹ Ref. (2), p. 29.

³² Ref. (2), p. 29.

³³ Ref. (2), p. 29.

³⁴ Ref. (2), p. 32.

induced current sent over the line would correspond to the direction of the motion of the reed, being positive when the reed moved in one direction and negative when it moved in the other; and that the intensity of the current would correspond, from instant to instant, to the velocity of the movement of the reed, being the greatest when the reed was moving most rapidly and the weakest at the moment of slowest motion.

He next considered what effect would result from two or more reeds set into vibration simultaneously by a current of air. His line of thought, expressed in his own language, was as follows:

"Under these circumstances the reeds would sometimes be moving in the same direction, and sometimes in opposite directions. Suppose that each reed moved in such a direction as to produce upon the line wire an impulse of positive electricity, then the combined action of both reeds at the same time should produce a positive impulse of greater strength than if either moved alone.

"On the other hand, if the motion of one reed tended to produce a positive impulse at the same time that the motion of the other reed induced a negative effect, then the reeds would tend to neutralize each other's action. Only a residual effect would appear upon the line wire, which would be positive or negative according to which reed produced the strongest effect. While, then, both reeds are producing electrical effects of the same kind—that is, both positive or both negative—the resultant effect upon the line wire should be the sum of the two impulses; but at the time when the reeds are producing electrical effects of opposite kind—one positive and the other negative—the resultant effect upon the line wire should be the difference of the two. If we should represent graphically, by a curve, the movement of the one reed, A, while producing its musical tone; and by another curve, the movement of the other reed, B; these curves would also represent in a graphical manner the electrical variations produced in the circuit by the vibration of each reed. The resultant electrical effect produced upon the line wire by the simultaneous vibration of both reeds would then be expressed by a curve representing the algebraical sum of the two curves considered."⁸⁵

⁸⁵ Ref. (2), p. 33.

In the light of this appreciation of the likeness between the aerial changes produced by the vibration of two reeds and the electrical changes on the line wire, Bell began to study⁸⁶ the resemblances more closely and saw that the effect was not confined to the operation of two reeds, but that a similar result would follow if he had a multitude of reeds of different pitch, each reed having its own electromagnetic coil, and all the coils being connected in one circuit. Then (still in the summer of 1874) the thought occurred to him—instead of an electromagnetic coil for each reed, why not have one electromagnet for the whole with all the reeds opposite its pole and let the resultant effect be induced in the coil of that one electromagnet, instead of inducing separate impulses in distinct and separate electromagnets and then combining the whole into a resultant upon the circuit.

This line of thought led him to the conception of the "harp" apparatus⁸⁷ shown in Figure 1. Identical instruments were to be used

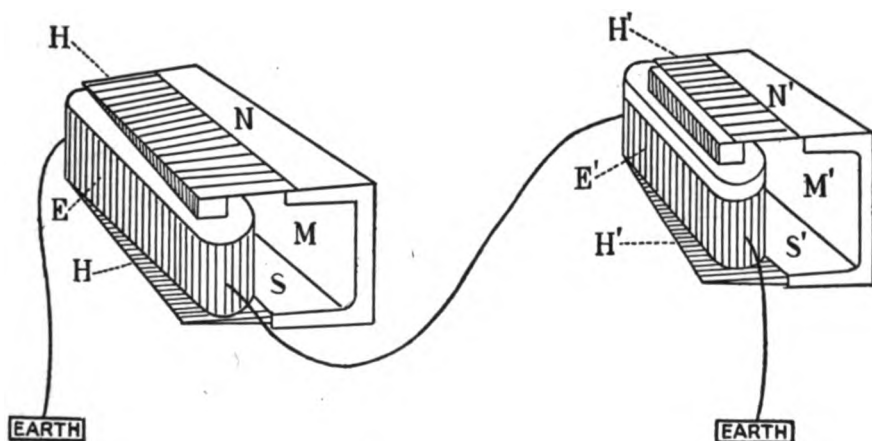


FIG. 1—BELL'S CONCEPTION OF HIS "HARP" APPARATUS

"A series of steel reeds was to be arranged so as to form a sort of harp, H, H, each reed having a different pitch. One end of each reed was to be in magnetical contact with one pole of a permanent magnet M, a single permanent magnet being employed for all the reeds. An elongated electromagnet E was to be placed between the two series of reeds so that the free end of each reed might be pretty close to the pole of the electromagnet, without touching it. A similar harp arrangement was to be used at either end of the circuit, and each instrument was capable of employment either as a transmitter or receiver." (From Bell's Deposition in the U. S. Government Suit.)

⁸⁶ Ref. (2), p. 34.

⁸⁷ Ref. (2), pp. 34, 35.

at either end of the line and each instrument was to be capable of use either as a transmitter or receiver. Two series of steel reeds, each having a different pitch, and all polarized from a single permanent magnet, were to be placed opposite the pole-pieces of a wide electromagnet, so that the free end of each reed would be close to one of the poles of the electromagnet, but not so close as to touch it. Although Bell did not have this "harp" apparatus constructed,³⁸ he had a clear mental picture that if one of the reeds of the harp at one end of the line were caused to vibrate, electrical undulations would be set up in the line and the reed of corresponding pitch in the harp at the other end of the line would be thrown into vibration, the intensity of its vibration corresponding to the amplitude of vibration of the transmitting reed. That is, not only would the reeds of the receiving harp produce musical tones of similar pitch to those emitted by the vibrating reeds of the transmitting harp, but also the relative loudnesses of the sounds would be preserved.

And now Bell's musical training and experience came into play. He already knew that, by depressing the "forte" pedal of a piano so as to raise the dampers from the strings, and singing into the instrument, certain of the strings could be set into sympathetic vibration by the voice, those strings responding which corresponded in pitch to the notes sung by the voice.³⁹ He reasoned that if he were to sing to his harp as he might sing to a piano a similar effect would be produced. His knowledge of Helmholtz's researches told him that when he sang a vowel sound he produced a sound that was composite in character, consisting of a loud fundamental tone, with relatively feeble overtones, or partial tones, mingled with it. He saw that, upon singing a vowel sound to the reeds of his harp, the reed corresponding in pitch to the fundamental tone of his voice, would be thrown into vigorous vibration; and that other reeds, corresponding in pitch to the overtones characteristic of the vowel sound, would be thrown into feeble vibration; and that all of these vibrations transmitted over the line and reproduced by the receiving harp with the relative loudnesses of the tones preserved would reproduce his singing of the vowel sound, the fidelity of the reproduction being increased in proportion to the number of reeds employed and the increasingly slight differences of pitch between adjacent reeds in the scale. In this way he realized, in the

³⁸ Ref. (2), p. 37.

³⁹ Ref. (2), pp. 36, 37.

summer of 1874, a conception of a speaking telephone; and the harp apparatus is historically important because it was the first form of speaking telephone that occurred to his mind.⁴⁰ He did not attempt to construct the apparatus because he realized its impracticability on account of the multitude of reeds that would be required. But he continued steadfastly to apply his mind to the working out of his idea in practical form and, while studying the theoretical operation of his harp arrangement in transmitting the quality or timbre of a sound, he was led to the conception of a great simplification of the apparatus employed. Hitherto he had thought of the action of the voice as causing the simultaneous vibration of a number of reeds with different degrees of force corresponding to the fundamental and over-tones of the voice; but, as he planned to use only one electromagnet for all the reeds, a single resultant electrical effect was to be produced in the coil of that electromagnet. Why, he now thought, cannot this resultant effect be produced equally well by a single reed, provided it be forced to move in the resultant path?

His experiments with the manometric capsule and the phonautograph⁴¹ had shown him that, however many speech sounds might be produced in the same room at the same time, the result as exhibited graphically in these instruments was the resultant of all the vibrations in the air. He concluded that a single reed would do the work in like manner if it could be made to vibrate like the diaphragm of the manometric capsule or the membrane at the end of the speaking-trumpet of the phonautograph.

The question was how to move a piece of steel in the way that the air was moved by the action of the voice.⁴² While this problem was in his mind, he was carrying on experiments with the phonautograph constructed from the human ear which Dr. Blake had prepared for him. The membrane of this ear could not have been as much as half an inch in diameter and it appeared to be as thin as tissue paper.

If such a thin and delicate membrane could move the relatively massive bones of the ear, why, thought he, should not a larger and stouter membrane be able to move a piece of steel in the manner that he desired?

It was then, in the summer of 1874, that the conception of a mem-

⁴⁰ Ref. (2), pp. 37, 38.

⁴¹ Ref. (2), p. 38.

⁴² Ref. (2), p. 39.

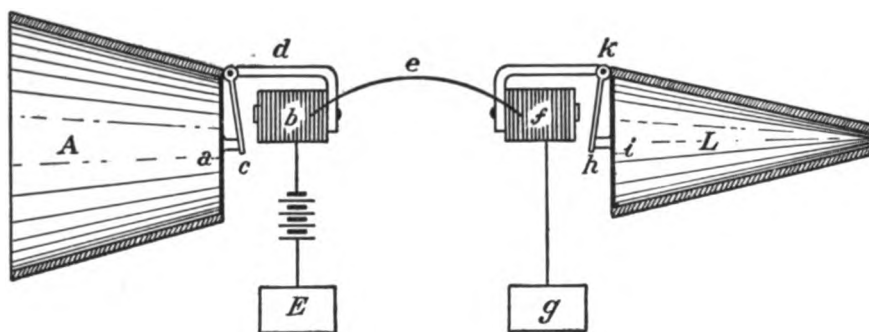


FIG. 2—"FIGURE 7" FROM BELL'S PATENT NO. 174,465, MARCH 7, 1876

"The armature c, Fig. 7, is fastened loosely by one extremity to the uncovered leg d of the electromagnet b, and its other extremity is attached to the center of a stretched membrane a. A cone, A, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane a is set in vibration, the armature c is forced to partake of the motion, and thus electrical undulations are created upon the circuit Ebefg. These undulation are similar to the air vibrations caused by the sound—that is, they are represented graphically by similar curves. The undulatory current passing through the electromagnet f influences its armature h to copy the motion of armature c. A similar sound to that uttered into A is then heard to proceed from L." (From Bell's U. S. Patent No. 174,465.)

brane speaking telephone became complete in Bell's mind,⁴³ for he perceived that a similar instrument to that used as a transmitter, could also be employed as a receiver. His plan was to attach the free end of a reed to the center of a stretched membrane, but instead of firmly fastening the reed to the pole of a permanent magnet, the magnet pole was simply to be brought into close proximity to the hinged end of the reed, so as to polarize it by magnetic induction. The arrangement thus conceived was substantially similar to that subsequently shown as "Figure 7," of his famous U. S. patent No. 174,465, of March 7, 1876, which is reproduced in Figure 2.⁴⁴

The historical narrative of this chapter brings out the successive steps by which the original idea of the telephone (so far, a mental concept, only) emerged from Bell's work on his harmonic telegraph and from his experiments with the phonautograph and the human ear. From the harmonic telegraph came the polarized movable reed placed in front of the pole of an electromagnet; from the phonautograph and

⁴³ Ref. (2), p. 39.

⁴⁴ Ref. (2), p. 39.

the human ear came the membrane diaphragm to which Bell attached his movable reed. Telephonists and others interested in telephony cannot fail to be impressed by the logical progress of Bell's experimenting and reasoning as, step by step, he pioneered the way to his goal. The next chapter will be devoted to Bell's work of developing his concept and making instruments that would talk. So far, he had conceived an idea. The actual transmission of speech electrically remained to be accomplished.

CHAPTER II

ALEXANDER GRAHAM BELL: THE INVENTION OF THE TELEPHONE AND ITS REDUCTION TO PRACTICE

ALTHOUGH Bell was satisfied that the apparatus which he had in mind constituted a theoretically perfect speaking telephone, he doubted whether the electrical currents, generated by the action of the voice alone, would be of sufficient strength to produce distinctly audible sounds from a receiving telephone at the end of a real line.¹ He did not immediately take steps toward constructing working apparatus for this reason and also because models for experimentation would cost considerable money and his financial resources were low.

Happily, in the autumn of 1874, two of his friends came to him voluntarily with offers of pecuniary aid.² One of these men was Mr. Thomas Sanders, a leather merchant of Haverhill, Massachusetts, the father of his former pupil, the lad George Sanders. Mr. Sanders had never ceased to feel a debt of gratitude to Bell for the successful tutoring of his son. Bell's other friend who offered to become his backer was the Hon. Gardiner Greene Hubbard. This narrative will be clarified at several points by digressing for a few moments to explain the circumstances of the acquaintanceship of Mr. Hubbard with Bell and his work. Hubbard was a lawyer, practicing in Boston and residing across the Charles River in Cambridge. He was a public-spirited citizen with many interests, active in promoting matters of public welfare and civic improvement, and a member of the Massachusetts State Board of Education. In the winter of 1861-1862, Mr. Hubbard's four-year-old daughter, Mabel, was stricken with a severe attack of scarlet fever which, unfortunately, left the little girl totally deaf. This misfortune naturally led Mr. Hubbard to investigate the existing means of communication for those afflicted with deafness. He found that the prevailing manual-sign language made communication possible, but adepts in its use were almost wholly confined to teachers of the deaf and those who were themselves deaf.

¹ Ref. (2), p. 40.

² Ref. (8).

Realizing the restricted field of this system, Mr. Hubbard sought further and learned of a system of lip-reading, then but little taught in America. With this method, the deaf, by watching the lips of any speaker, could follow what was said and could also be taught to speak intelligibly. Convinced that the latter method possessed vast advantages over the manual-sign system, Hubbard became its strong advocate. Desiring that others similarly afflicted might share freely in the benefits of what was turning out to be good for his own daughter, Hubbard urged the Massachusetts Legislature, in 1864, to grant a charter for an institution for the education of the deaf in the lip-reading method and to make an appropriation of money to its support.³ His efforts bore fruit three years later, when a charter was granted and the Clarke Institution for Deaf-Mutes, at Northampton, Massachusetts, was organized.

In the fall of 1868, Professor Alexander Melville Bell, the father of Alexander Graham Bell, made a journey to America⁴ to deliver a course of lectures in Boston under the auspices of the Lowell Institute. These lectures, describing what had been done for deaf children in London by means of his system of visible speech, gave support to the movement that Hubbard was sponsoring, and, in the following year, a day school for the deaf, which subsequently became the Horace Mann School, was inaugurated as a part of the public school system of Boston, with Miss Sarah Fuller in charge as principal.⁵ Bell's father returned in 1870 to give another course of Lowell Institute lectures. Learning that he was to spend six weeks in Boston, Miss Fuller sought to make arrangements for him to instruct her staff of teachers in his methods of visible speech during his stay. His other engagements rendered this impracticable, but he took the opportunity to explain that his son, Graham, had met with great success in introducing his methods into the school for deaf children in London, and could probably come to Boston for a like purpose. Miss Fuller, supported by the Rev. Dexter S. King, a member of the Boston School Board, took up energetically the matter of bringing the younger Bell to Boston for this work, and his visit, in April, 1871, mentioned in the foregoing chapter, grew out of these incidents.

³ Ref. (8).

⁴ Ref. (8).

⁵ Ref. (8).

These were the circumstances under which Hubbard had come to know Bell. By the autumn of 1874 their acquaintanceship was already of three years duration. Throughout this time they had been closely associated in the work for the deaf and Bell had been a frequent visitor at Mr. Hubbard's home. Hubbard therefore knew of Bell's electrical experimenting and his ideas for telegraphing and telephoning. In them, he had the vision to see promises of practical commercial value. Accordingly, without any solicitation on Bell's part, Hubbard made Bell an offer to furnish him the money that he needed for his electrical experiments, taking in return a half interest in such inventions and patents as might result. As already mentioned, Mr. Sanders, only a few days previously, had made Bell a similar proposition. So a meeting of the three friends was arranged at which they agreed to form a partnership⁶—Sanders and Hubbard each to supply half the money that Bell needed and each to receive a one-third interest in such patents as might eventuate. So informal was the agreement that its terms were not reduced to writing at that time.

With his financial burdens eased, Bell pursued his work. During the latter part of November, 1874, in the course of further experimenting, he noted that a sound was emitted by the solid iron core of an electromagnet when the latter was placed in a circuit with one of his current interrupters. In a letter to Mr. Hubbard describing this interesting fact, he wrote:

"I have been reflecting all the evening upon the cause of this strange phenomenon, and I think that I have discovered it. The solution, if correct, points to other still stranger phenomena. My idea is this: When a current of electricity passes through the coils of an electromagnet, the molecules of iron in the core become magnetic and attract each other, approaching nearer together than they were. When the current stops, they resume their former places. This is borne out by the fact (that I have read somewhere) that a soft iron bar becomes shorter on being magnetized. Hence an intermittent current of electricity passed through the coils of an electromagnet should induce a molecular vibration in the core; and perhaps this molecular vibration may have been the cause of the sounds heard by me this evening."⁷

⁶ Ref. (21).

⁷ Ref. (2), p. 43.

In February, 1875, Bell put off all pupils and classes and visited Washington, D. C., in connection with the preparation of three of his patent applications relating to his inventions in multiple telegraphy. He remained in Washington about a month. While there he called upon Professor Joseph Henry, the distinguished American scientist who was the secretary of the Smithsonian Institution. Concerning the interview, Bell, upon his return to Salem, wrote to his parents as follows:

"When I was in Washington I had a letter of introduction to Professor Henry, who is the Tyndall of America. I had found on inquiry at the Institute of Technology, that some of the points I had discovered in relation to the application of acoustics to telegraphy had been previously discovered by him. I thought I would, therefore, explain all the experiments, and ascertain what was new and what was old. He listened with an unmoved countenance, but with evident interest to all, but when I related an experiment that at first sight seems unimportant, I was startled at the sudden interest manifested.

"I told him that on passing an intermittent current of electricity through an empty helix of insulated copper wire, a noise could be heard proceeding from the coil, similar to that heard from the telephone.* He started up, said, 'Is that so? Will you allow me, Mr. Bell, to repeat your experiments, and publish them to the world through the Smithsonian Institute, of course giving you the credit of the discoveries?'

"I said it would give me extreme pleasure, and added that I had apparatus in Washington, and could show him the experiments at any time. He asked if I could do it *then*, if he went with me, and I told him that I had everything in readiness at Mr. Hubbard's house. He said, 'I will go with you now. Have you a carriage here?' I had not, and so he put on his coat and was about to order his carriage, when I offered to save him the trouble of going out on such a raw, damp day, by bringing the

* The reference was to the so-called telephone made by Reis, of Germany, in 1860. It was a device which was operated by a "make-and-break" current. It could transmit the pitch but not the quality of a sound. In the opinion of the Circuit Court of the U. S., District of Massachusetts, No. 1,424, June 27, 1881, Judge Lowell said: "articulate speech could not be sent and received by it." . . . "The deficiency was inherent in the principle of the machine." . . . "A century of Reis would never have produced a speaking telephone by mere improvement in construction."

apparatus to the Smithsonian Institute. (He was suffering from a cold, and besides is very aged,—I believe about eighty years old.)

"We appointed noon next day for the experiment. I set the instrument working and he sat at a table for a long time with the empty coil of wire against his ear listening to the sound. I felt so much encouraged by his interest that I determined to ask his advice about the apparatus I have designed for the transmission of the human voice by telegraph. I explained the idea and said, 'What would you advise me to do, publish it and let others work it out, or attempt to solve the problem myself?'

"He said he thought it was 'the germ of a great invention,' and advised me to work at it myself instead of publishing. I said that I recognized the fact that there were mechanical difficulties in the way that rendered the plan impracticable at the present time. I added that I felt that I had not the electrical knowledge necessary to overcome the difficulties. His laconic answer was, 'GET IT.'

"I cannot tell you how much these two words have encouraged me. I live too much in an atmosphere of discouragement for scientific pursuits. . . . Such a chimerical idea as telegraphing vocal sounds would indeed to most minds seem scarcely feasible enough to spend time in working over. I believe, however, that it is feasible, and I have got the cue to the solution of the problem.

"Professor Henry seemed to be much interested in what I told him, and cross-questioned me about my past life, and specially wanted to know where I had studied physics."⁸

Heartened by his meeting with Professor Henry, Bell returned to his experimenting. Now that he had, thanks to Mr. Sanders and Mr. Hubbard, the means to have apparatus constructed for him, he betook himself to the electrical shop of Charles Williams, Jr., 109 Court Street, Boston. Williams's shop was a place where school apparatus, telegraph instruments, annunciators, call bells, and other electrical apparatus were made. Inventors also employed its facilities for the construction of experimental apparatus embodying their ideas in practical form. Among the mechanics employed in this shop was Thomas A. Watson, then about twenty years of age, who had just completed his apprenticeship as a maker of electrical apparatus. Wat-

⁸ Ref. (2), pp. 46, 47, 48.

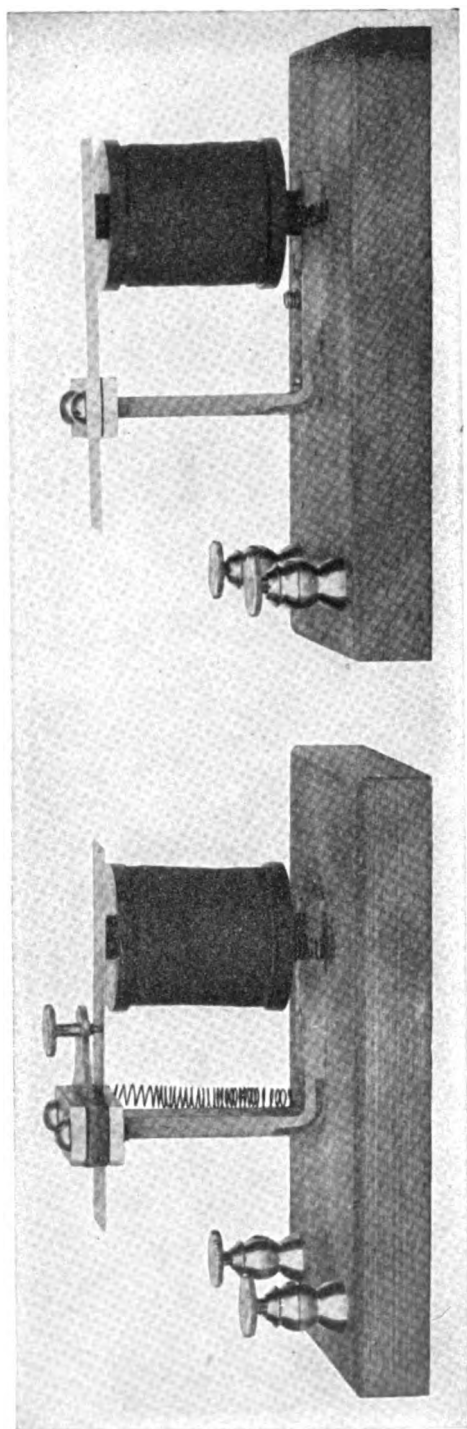


FIG. 3.—Bell's Multiple Harmonic Telegraph Apparatus. Transmitting instrument at left; receiving instrument at right.

son, at that time, was principally occupied in work for inventors and he was assigned to perform such work as Bell desired to have done. Sanders and Hubbard were urging Bell to perfect his harmonic telegraph, as it promised greater and more immediate returns than his ideas for a telephone which seemed to them visionary in comparison.⁹ The duplex telegraph for sending two messages simultaneously over one wire had just been invented by J. B. Stearns, and Bell was confident that at least six or eight simultaneous messages could be sent by his method as soon as it was perfected.¹⁰ Bell had therefore caused Watson to make three sets of multiple telegraph apparatus (Fig. 3). These were set up for experimenting in the top story of the Williams building, where Bell had obtained the use of two rooms, perhaps sixty feet apart, with a line wire connecting them.¹¹

On June 2, 1875,¹² Bell, with Watson's assistance, was ready to make a trial of this apparatus, which consisted of three circuit-breaking transmitters, tuned to different pitches, each provided with a telegraphic key to connect it with the line wire as desired; and two sets of tuned-reed receivers, each set consisting of three instruments having the same pitches as the transmitting instruments. In one room were the three transmitting instruments and a receiving station equipped with one set of the tuned-reed receivers. The remaining set of three tuned-reed receivers was in the other room at the end of the line wire. While experimenting, either Bell or Watson would operate the keys of the transmitting instruments while the other remained at the receiving station at the "far" end of the line—that is, in the other room.¹³ The mode of experimenting was to depress one of the keys at the transmitting station and to observe the receiving instruments in the same room to ascertain whether the corresponding one was thrown into good vibration. Meanwhile, in the other room, Bell or Watson would observe whether his corresponding receiving instrument was vibrating well. If the vibrations were not satisfactory, the two experimenters would tune the proper receivers by shortening or lengthening the free part of the reed armature, according as the pitch was lower or higher than that desired. Sometimes they found that the reed armature was so closely adjusted to the pole of the electromagnet below it that it

⁹ Ref. (6); also Ref. (2), p. 94.

¹⁰ Ref. (6).

¹¹ Ref. (3).

¹² Ref. (2), p. 57 *et seq.*

¹³ Ref. (2), p. 58.

would stick to the pole, instead of vibrating, the moment a current was passed through the electromagnet. They would then release the armature by plucking it with their fingers, and if it still stuck fast every time a current passed through its magnet coil, they would bend it so as to cause its free end to be normally a little farther away from the magnet pole. As Watson says, "Try our best, we could not make that thing work rightly, and Bell came as near to being discouraged as I ever knew him to be."¹⁴ In this case, at least, it was darkest just before the dawn.

Mr. Watson has described the crucial moment in graphic, living language:

"I had charge of the transmitters as usual, setting them squealing one after the other, while Bell was retuning* the receiver springs one by one, pressing them against his ear. . . . One of the transmitter springs I was attending to stopped vibrating and I plucked it to start it again. It didn't start and I kept on plucking it, when suddenly I heard a shout from Bell in the next room, and then out he came with a rush, demanding: 'What did you do then? Don't change anything! Let me see?' I showed him. It was very simple."¹⁵

The make-and-break points of the transmitter spring which Watson was trying to start had accidentally been brought into permanent contact, so that when he snapped the spring the circuit had remained unbroken. Watson has said:

" . . . that strip of magnetized steel, by its vibration over the pole of its magnet, was generating that marvelous conception of Bell's—a current of electricity that varied in intensity precisely as the air was varying in density within hearing distance of that spring. That undulatory current had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform that current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly

* On account of Bell's musical training and the accuracy of his ear, he always attended personally to the tuning of the receiver reeds.

¹⁴ Ref. (3).

¹⁵ Ref. (3).

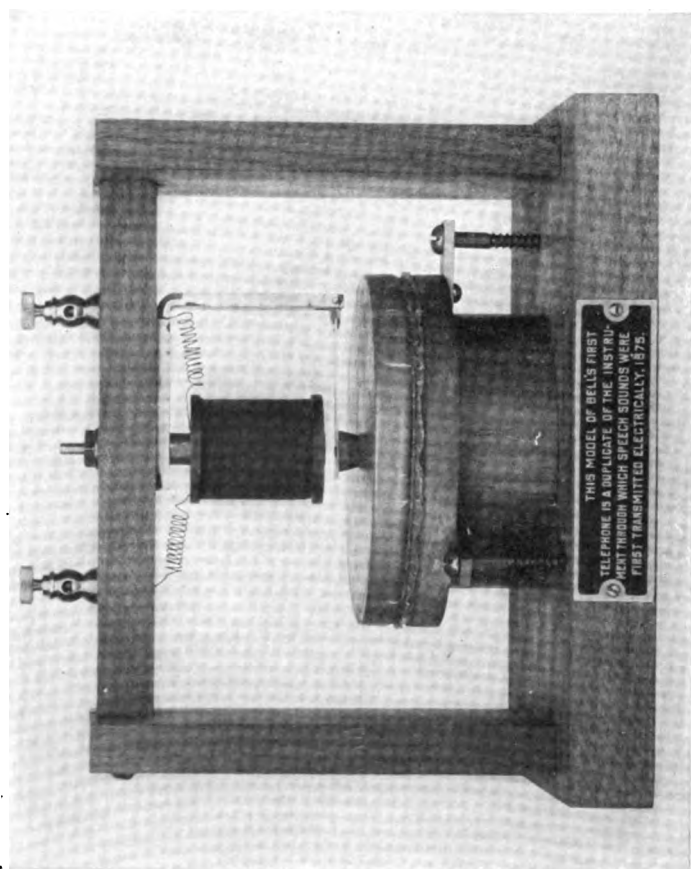


FIG. 4-A—Bell's First Electric Speaking Telephone. This instrument was constructed by Watson, June 3, 1875. Due to the shape of its frame, it was termed the "Gallows" telephone.

recognized the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room were the result of that recognition. The speaking telephone was born at that moment."¹⁶

It is interesting to note that when Bell held his harmonic receiver tightly against his ear, he in effect clamped the free end of the reed or spring, thus damping its natural rate of vibration and causing it instead to vibrate in a manner analogous to the diaphragm of the modern telephone receiver. For a long time Bell kept Watson plucking the reeds while he himself pressed the reeds of the several receivers successively against his own ear. At every pluck he not only heard a musical tone of similar pitch to that produced by the instrument in Watson's hands, but he could recognize the peculiar quality or timbre of the pluck. He and Watson frequently changed places with the same result.¹⁷ In the calm, unemotional language of a deposition in a patent suit, Bell subsequently said:

"These experiments at once removed the doubt that had been in my mind since the summer of 1874, that magneto-electric currents generated by the vibration of an armature in front of an electromagnet would be too feeble to produce audible effects that could be practically utilized for the purposes of multiple telegraphy and of speech transmission."¹⁸

The next step was to construct the first speaking telephone. Before Bell and Watson parted that night, after spending the remainder of the day in snapping steel springs of many shapes and tuning forks of many sizes before electromagnets with the same astonishing result, Bell gave Watson the directions for making it.¹⁹ One of the harmonic receivers was to be mounted in a wooden frame, the free end of its spring to be fastened to a small bit of cork attached to the middle point of a drumhead or diaphragm of tightly stretched parchment, likewise mounted in the wooden frame. There was also to be a mouth-piece for concentrating the voice waves upon the opposite side of the

¹⁶ Ref. (3).

¹⁷ Ref. (2), p. 59.

¹⁸ Ref. (2), p. 59.

¹⁹ Ref. (3).

parchment diaphragm²⁰ (Figs. 4-A and 4-B). Under the date of June 2, 1875, Bell wrote to Hubbard from Salem, presumably when he reached home in the evening, a brief letter in the course of which he said, "I have succeeded today in transmitting signals without any battery whatever!"

On the next day, June 3, 1875, Watson built the first electric

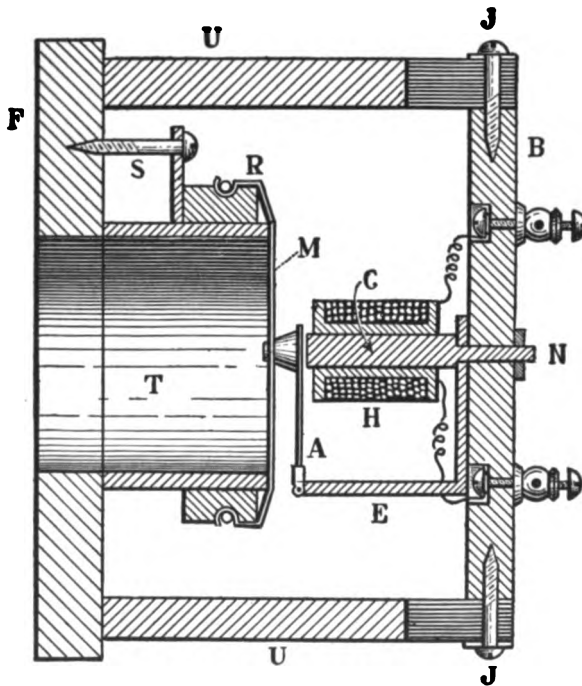


FIG. 4-B.—CROSS-SECTION OF FIRST ELECTRIC SPEAKING TELEPHONE

In this earlier arrangement, a membrane M is attached to a straining ring R, carrying three metallic projections, through which screws S pass into a board F. By the operation of screws S the membrane M can be stretched tightly across the end of a tube T. Attached to the board F are side-pieces U, U carrying a crossbar B, which is retained in position in the slotted ends of the side-pieces by screws J, J. The crossbar B supports an electromagnet H, E, which is attached to the crossbar by a screw and nut at N. The leg C of the electromagnet is covered with a coil H of insulated copper wire, and to the uncovered leg E of the electromagnet is pivoted one end of the steel armature A, the other end being attached to the center of the strained membrane M.

The drawing shows a piece of cork between the center of the membrane and the end of the armature or reed.

²⁰ Ref. (6).

speaking * telephone in the world, making every part of the instrument with his own hands.²¹ It was tested on the evening of the same day. Realizing that the sounds to be heard would, at the best, be very faint, Watson took the precaution to run an insulated wire about two hundred feet long from one of the fifth floor rooms (where the tests had been made on the previous day) to his own work-bench on the third floor, in order to avoid any possible overhearing by the transmission of the sound waves through the air.

In the evening Bell came for the test. The workmen in the shop had left for the day, so he and Watson had the dingy old building to themselves. The new telephone was adjusted, placed on Watson's work-bench, and connected to the wire. Bell stationed himself in the attic room where, by means of one of the harmonic telegraph receivers,²² he listened, straining his ear to hear Watson's voice, speaking into the new telephone two floors below. Watson shouted, but Bell could hear nothing.²³ They then exchanged places, Bell talking downstairs and Watson listening in the room above. Watson has said: "I could unmistakably hear the tones of his voice and almost catch a word now and then. I rushed downstairs and told him what I had heard."²⁴ Beyond doubt the overtones characteristic of the quality or timbre of speech sounds had been electrically transmitted and received.

The ensuing months witnessed many experiments in which it was sought to improve the arrangement of the parts of the instrument to produce more powerful effects. Another stretched membrane instrument was used as a receiver.²⁵

Several circumstances arose which caused delays in Bell's work of developing his invention. During the summer of 1875, he was in poor health,²⁶ able to carry on few experiments, and forced to spend his spare time chiefly with thinking over the results he had obtained and trying to determine what to do next. He was also seeking aid

* The use of the words "electric speaking telephone" is due to the fact that the word "telephone," derived from the Greek $\tau\eta\lambda\epsilon$, meaning "distant" or "afar," and $\phi\omega\nu\eta$, meaning "to hear" was used before Bell made his invention. Early uses of the word are described in Appendix B.

²¹ Ref. (7), p. 69.

²² Ref. (7), p. 71.

²³ Ref. (6), p. 1017.

²⁴ Ref. (7), p. 71.

²⁵ Ref. (2), p. 67.

²⁶ Ref. (2), p. 74; Ref. (7), p. 76.

in obtaining foreign patents on his multiple telegraph inventions, and he had to devote considerable time to drafting the specifications and claims which ultimately resulted in his basic U. S. Patent No. 174,465, granted March 7, 1876, covering the telephone.²⁷ From the drafts which he wrote and rewrote, resulted the fifth claim of that patent which so cogently sums up his invention :

“The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth.”

His patent application was not filed until February 14, 1876, as it was desired to make arrangements for taking out patents simultaneously in Europe.²⁸ It is interesting to note that his U. S. patent was issued three weeks after his application was filed.

Then, too, he was pressed financially. His professional work of teaching had become disorganized as the result of the zeal with which he had plunged into his experimenting to the exclusion of almost everything else. While his associates, Mr. Sanders and Mr. Hubbard, had agreed to pay for the construction of his apparatus, no provision had been made to recompense him for the time he was spending on the development of his inventions.²⁹ He knew that his professional work was capable of yielding him a livelihood, but he desired earnestly to give it up, at least for a time, in order to devote himself uninterruptedly to his electrical researches.³⁰ As Mr. Sanders had already spent considerable money on Bell's work, without return, Bell was reluctant to request further advances from him, and he felt himself estopped from applying to Mr. Hubbard for money for his support on account of what he termed “delicate relations” that had arisen between himself and the Hubbard family to which brief reference must now be made.³¹

By the time Mr. Hubbard's daughter had reached the age of nine she had made remarkable progress in lip-reading. As a result, her general education was not a whit behind that of children of her age who could hear, and she had mastered the art of speaking.

²⁷ Ref. (2), p. 76.

²⁸ Ref. (2), p. 80.

²⁹ Ref. (2), p. 88.

³⁰ Ref. (2), p. 89.

³¹ Ref. (2), pp. 88, 89.

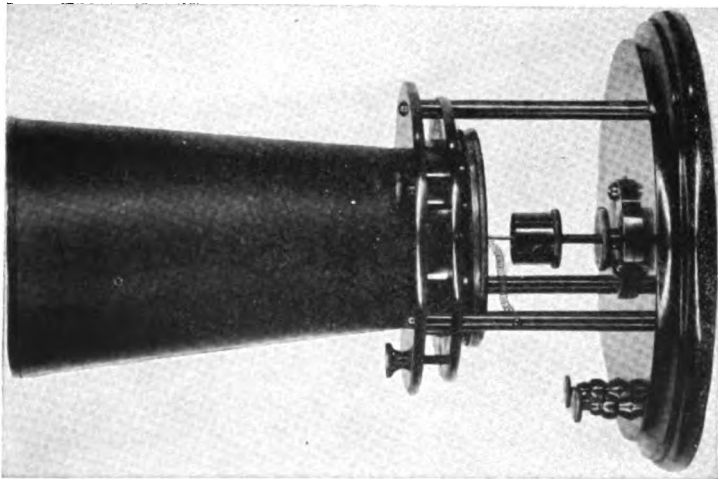


FIG. 5

FIG. 5—Bell's Liquid Transmitter.

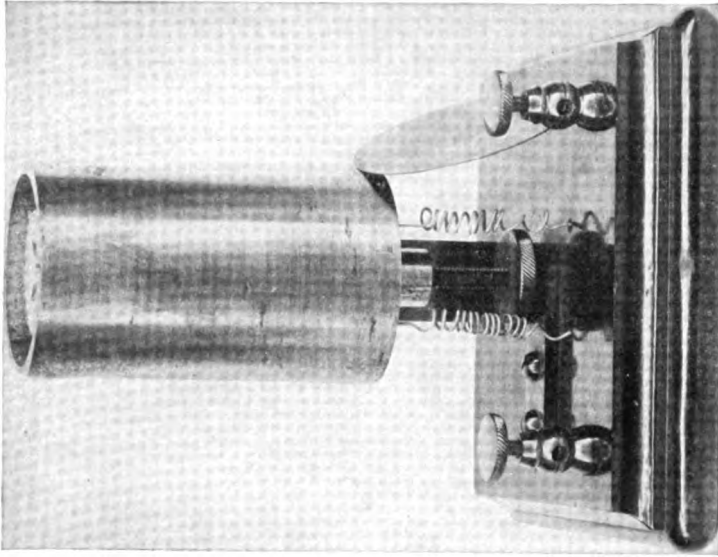


FIG. 6

FIG. 6—Bell's Iron-Box Receiver. The diaphragm, which normally lay horizontally on the top of the cylindrical shell, has been removed to render the central pole-piece visible, and is resting on the base.

In 1870, she had been taken to Germany, where education in lip-reading was further advanced than in any other part of the world. There she progressed even further.³²

When she returned to America she was a young lady of seventeen. Bell, of course, met her at her father's house, but he was not her teacher.³³ The young people naturally saw much of each other and their friendship speedily ripened into love. So matters stood at this time, Bell desiring to place himself, pecuniarily, in a position such that he should be able to marry Miss Hubbard.³⁴ He knew that his professional work, if continued, could yield him a modest income; but he was confident that, if he devoted his attention exclusively to his electrical inventions, they would bring him a fortune. He decided that the quickest way of getting back to his electrical researches would be to devote his time for a while to his professional work.

This plan he carried out in the fall of 1875, lecturing to large classes in normal schools and building up a considerable clientele of private pupils.³⁵ Early in the following year, members of his normal school classes had become sufficiently proficient to relieve him of the burden of private teaching. At about the same time he had also completed arrangements with the Hon. George Brown of Toronto and his brother, Mr. Gordon Brown, friends who were aiding him in taking out foreign patents, to pay the expenses of private rooms where he could keep his electrical apparatus.³⁶ This he was desirous of doing since rumors had reached him of strangers, visiting the Williams shop and examining his apparatus with curious eyes.³⁷

He accordingly engaged two rooms in a boarding house at No. 5 Exeter Place, Boston, to which, in January, 1876, he removed his apparatus.³⁸

Thus almost simultaneously he came into possession of the place and the time for further experimental work to which he applied himself with his accustomed zeal, still relying on Mr. Watson to construct his apparatus and to aid him, at night, in testing it.³⁹

He soon found time to work on an electric spark arrester for use

³² Ref. (8).

³³ Ref. (8).

³⁴ Ref. (2), p. 89.

³⁵ Ref. (2), p. 90.

³⁶ Ref. (2), p. 90.

³⁷ Ref. (2), p. 90.

³⁸ Ref. (2), p. 91.

³⁹ Ref. (7), p. 76.

with his multiple telegraph.⁴⁰ In this he regulated the resistance between two wires by dipping their ends into a vessel of water, varying the resistance by adjusting the depth to which the wires were submerged. Out of this device came to him the idea that similar means would be eminently suitable as a variable resistance mode of producing electrical undulations stronger than those which he had obtained from his magneto-electric instruments.⁴¹ The liquid transmitter which he developed out of this idea is shown in Figure 5.

In this instrument a wire attached to a voice-operated diaphragm dipped into a cup of acidulated water, the cup with its conducting liquid and the movable wire forming part of an electrical circuit containing also a battery and a receiving telephone. As the diaphragm vibrated, the wire rose and fell, subject to its control, in the liquid, thus causing the resistance of the circuit to change and the current to vary in conformity to the sound waves set up by the voice and directed upon the diaphragm.⁴²

With this apparatus * and a wire line extending from Bell's laboratory room to his bedroom in the house at No. 5 Exeter Place, on March 10, 1876, Bell spoke, and Watson heard the first complete sentence ever transmitted by the telephone. It was, "Mr. Watson, come here; I want you."^{43†}

At last the electric speaking telephone had spoken so clearly that doubt no longer existed as to its capability of transmitting articulate speech.

The not far distant future was destined to see a wide variety of transmitters—the inventions of many men—employing microphonic contacts between carbon and metal or between carbon in the form of blocks or granules. These were all variable resistance transmitters. Let it not be overlooked, at this juncture, that Bell's liquid transmitter was the first variable resistance transmitter and that the germ of the principle was due to him.

⁴⁰Ref. (2), p. 84.

⁴¹Ref. (2), p. 86.

⁴²Ref. (2), p. 87.

* The receiving instrument was a tuned-reed receiver.⁴³

⁴³Ref. (2), p. 93.

⁴⁴Ref. (7), pp. 77, 78.

† Other versions that have found their way into print are "Watson, come here; I want you," and "Mr. Watson, please come here; I want you." The correct version is contained in Mr. Watson's original notebook which is now preserved in the American Telephone Historical Collection.

CHAPTER III

ALEXANDER GRAHAM BELL: DEMONSTRATING THE TELEPHONE AND FURTHER IMPROVING IT

DURING 1876, Bell began to give more attention to the telephone than to his multiple telegraph inventions. Previous to that time, Messrs. Hubbard and Sanders had urged him to devote the chief part of his time to multiple telegraphy which they then expected would prove of more immediate pecuniary value than the telephone.¹

In the early part of 1876 (March or April), Bell found the opportunity to make a further improvement in his telephone. As already described, it had been his habit, while using a tuned-reed receiver, to get rid of the free vibration of the reed by pressing it closely against his ear in order to damp its natural period of vibration which was a disadvantage. It occurred to him to overcome this difficulty by fettering the free end of the reed so as to reduce its tendency to vibrate at a definite rate as much as possible.

For this purpose he at first proposed to clamp both ends of the reed and to attach them to two of the poles of a three-legged electro-magnet, but he soon perceived that a cylindrical iron box with a central core would answer the purpose better.²

With this latter arrangement, the end of the central core would constitute one pole of the tubular magnet thus formed and the rim of the iron box, the other pole (Fig. 6). By placing on the end of this magnet a lid or diaphragm of iron, he had an armature that was damped all around its periphery * and polarized by contact with the rim of the box.

This turned out to be an advantageous arrangement, and thereafter it was generally employed. He also made some use of it as a transmitter.

On May 10, 1876, Bell read a paper before the American Academy

¹ Ref. (2), p. 94.

² Ref. (2), p. 321, *et seq.*

* The peripheral clamping of the diaphragm is, of course, a feature of the modern telephone receiver.

of Arts and Sciences entitled "Researches in Telephony."³ On that occasion he exhibited a number of pieces of apparatus including membrane telephones, his new iron-box receiver, some circuit-breaking telegraph transmitters and tuned-reed receivers, and his liquid telephone transmitter. He had a wire connecting the hall of the American Academy with his private room in Boston University, which was almost next door, and over this wire he transmitted music from a parlor organ, the reeds of which were arranged to interrupt, in vibrating, an electric circuit. The iron-box receiver was used for listening. At the close of the meeting, the membrane telephones were shown in operation and some of the members of the Academy tested them on that occasion.

About two weeks later Professor Bell read substantially the same paper before the 197th meeting of the Society of Arts, held at the Massachusetts Institute of Technology in Boston.⁴

A report of this meeting, appearing in a newspaper, the *Boston Evening Transcript*, May 31, 1876,⁵ read as follows:

RESEARCHES IN TELEPHONY

Professor A. Graham Bell read a paper, illustrated by successful experiments, on "Telephony," or the telegraphing of musical sounds . . . The experiments were novel and successful and witnessed by a large audience, by whom a vote of thanks was passed to Professor Bell for his interesting paper.

During the summer of 1876, there was held in Philadelphia, Pa., an international exhibition including arts and manufactures. This exhibition, commemorating the one hundredth anniversary of American Independence, was known as the Centennial Exhibition.

Professor Bell placed some of his apparatus, including two membrane speaking telephones, a liquid speaking telephone transmitter, and an iron-box receiver on exhibition, and they remained there until the close of the Centennial.⁶ In the latter part of June, Bell went to Philadelphia for the purpose of exhibiting his apparatus to the judges of the Exhibition.⁷ This he did on Sunday, June 25. The Centennial was not open to the public on Sundays, and this was the reason that the judges chose that day to examine the electrical instruments and

³ Ref. (2), p. 95; Ref. (9).

⁴ Ref. (2), p. 96.

⁵ Ref. (2), p. 96.

⁶ Ref. (2), p. 96.

⁷ Ref. (2), p. 97.

instruments of precision. About fifty or sixty people were present, including the Emperor, Dom Pedro, and the Empress of Brazil; Sir William Thomson, chairman of one committee of judges; Joseph Henry, chairman of another committee of judges; Professor James C. Watson, of Ann Arbor, Michigan; Professor T. Sterry Hunt; Professor George F. Barker; Professor Hilyard; Dr. Draper; Dr. Koenig, the inventor of the manometric capsule, and Mr. Elisha Gray. A nephew of the Hon. Gardiner G. Hubbard, Mr. William H. Hubbard, assisted Bell in his experiments.⁸

The presence of Dom Pedro lent a dramatic touch to the exhibition. He remembered having met Professor Bell on a previous occasion in connection with Bell's work of teaching the deaf, and he greeted him. This incident in itself served to direct the attention to Professor Bell and his exhibit.⁹

The demonstration which Bell conducted impressed Sir William Thomson (later Lord Kelvin), already one of the most distinguished of British scientists and the chairman of the exhibition committee on Electrical Exhibits.

In describing the speaking telephone, upon his return to England in an address which he made to the British Association at Glasgow, Scotland, published in *Nature*, a scientific periodical of London, England, on September 14, 1876,¹⁰ he said:

"I heard 'To be or not to be . . . there's the rub,' through an electric telegraph wire; but, scorning monosyllables, the electric articulation rose to higher flights, and gave me messages taken at random from the New York newspapers: 'S. S. Cox has arrived' (I failed to make out the S. S. Cox); 'The City of New York'; 'Senator Morton'; 'The Senate has resolved to print a thousand extra copies'; 'The Americans in London have resolved to celebrate the coming 4th of July.' All this my own ears heard, spoken to me with unmistakable distinctness by the thin circular disk armature of just such another little electromagnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague judge, Professor Watson, at the far end of the telegraph wire, holding his mouth close to a stretched membrane, such as you see before you here, carrying

⁸ Ref. (2), pp. 100, 101.

⁹ Ref. (7), p. 84.

¹⁰ Ref. (10).

a little piece of soft iron, which was thus made to perform in the neighborhood of an electromagnet in circuit with the line, motions proportional to the sonoric motions of the air. This, the greatest by far of all the marvels of the electric telegraph, is due to a young countryman of our own, Mr. Graham Bell, of Edinburgh, Montreal, and Boston, now becoming a naturalized citizen * of the United States. Who can but admire the hardihood of invention which devised such very slight means to realize the mathematical conception that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously and, as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sound?"¹¹

On the very day of Bell's demonstration of his apparatus at the Centennial Exhibition, Professor T. Sterry Hunt wrote to him, from the Continental Hotel in Philadelphia, as follows:

"Dear Mr. Bell:

I am informed that you leave tonight for Boston, so I take this way of congratulating you on your success today. I returned to my hotel with Sir William Thomson, and dined with him. He speaks with much enthusiasm of your achievement. What yesterday he would have declared impossible he has today seen realized, and he declares it the most wonderful thing he has seen in America. You speak of it as an embryo invention, but to him it seems already complete, and he declares that, before long, friends will whisper their secrets over the electric wire. Your undulating current he declares a great and happy conception."¹²

From the Centennial Exhibition, Bell received a medal and a Certificate of Award, dated September 27, 1876, for his Electric Telephone and Multiple Telegraph.¹⁴

* Alexander Graham Bell declared his intention to become a citizen of the United States on October 27, 1874, before the Superior Court of the Commonwealth of Massachusetts, held at Lawrence, Massachusetts, while he was residing at Salem. He was admitted to become a citizen of the United States on November 10, 1882, before the Supreme Court of the District of Columbia.¹²

¹¹ Ref. (6), p. 1018.

¹² Ref. (2), p. 6.

¹³ Ref. (2), p. 101.

¹⁴ Ref. (2), p. 127.

General John J. Carty has said :

"I read a two-volume book by General Walker, an official report of the Centennial, and I looked through it in vain to find a word about the telephone. I have looked through many other volumes about the Centennial of 1876. There was much about the Corliss engine, and you will be surprised to know that there was much about the printing telegraph; there were threshing machines and Yankee notions of all kinds which received page after page of text and many full-page illustrations, but not a word about the telephone."¹⁵

On July 2 of the same year, Professor Bell wrote from Cambridge, Massachusetts, to Mr. William H. Hubbard, who had remained in Philadelphia in charge of Bell's exhibit :

"I am afraid you must think me very ungrateful for not having written, but the fact is, that in preparing for transmitting sounds to Philadelphia from here, I made such a startling discovery that I have been unable to do anything else since but experiment. In order to attempt the transmission of speech to Philadelphia,¹⁶ * it was necessary to have a telephone constructed, the magnet of which should have a resistance equivalent to a considerable portion of the total resistance of the telegraph line between here and Philadelphia. The resistance of the line is over 5,000 ohms. Now I have had two magnets made, the coils of which offer a resistance of 3,250 ohms both together. It would require a battery of many cells in order to operate a Morse sounder through such a resistance. It is as great a resistance as 325 miles of well-insulated telegraph wire. My discovery was that I could work my apparatus with one cell of battery through this resistance. I am sure by substituting a permanent magnet for the pole of the electromagnet, I could work it without a battery at all."¹⁷

¹⁵ Ref. (11).

¹⁶ Ref. (2), p. 111.

* Bell has stated that "If the judges of the Centennial had requested the experiment, I was prepared to attempt to transmit articulate speech from Boston to Philadelphia."¹⁸

¹⁷ Ref. (2), p. 107.

¹⁸ Ref. (2), p. 105.

In July, 1876, in the presence of Sir William Thomson, Professor Bell attempted to talk between two points in Boston connected by a wire reaching to New York and back. He has said:

"We telegraphed to New York, and had two wires crossed there, and we introduced this loop, exceeding 400 miles of wire, into our telephonic circuit. I remember that there had been a storm a short time before—probably the day before—and on that account many of the telegraph wires were out of order, and on this occasion, when the New York wires were crossed, there seemed to have been some trouble on the wires, which occasioned the most extraordinary noises from the telephones. A perfect storm of foreign sounds made their appearance, and I do not think we could get any speech through while the New York loop was in circuit. I remember also that when this experiment was made we tried the effect of short-circuiting the loop to New York, and at once the articulation of the telephone became audible. Vocal sounds were heard and the noises due to the loop disappeared. After the conclusion of the experiments of July 12, 1876, I presented the instruments used to Sir William Thomson as a memento of the occasion, and he carried them to England with him."¹⁹

Perhaps this book may come before the eyes of some "telephone man," ripe in years, who, in days long gone by, experienced "extraordinary noises from the telephone" and "a perfect storm of foreign sounds," but who, at the time, described these phenomena in language less carefully chosen than that of the inventor on this occasion!

Later in the summer of 1876, Professor Bell made his customary sojourn in Canada. In the first week of August, he tried the novel feat of transmitting the voices of three persons simultaneously. Said he:

"I had a triple mouthpiece made for one of my membrane telephones, and this was placed in one of the outbuildings on my father's place at Tutelo Heights, near Brantford. The iron-box receiver was placed upon the veranda of the house. Three persons spoke and sang simultaneously into the triple mouthpiece,

¹⁹ Ref. (2), pp. 114, 115.

and the three voices—words and all—were reproduced by the iron or steel diaphragm of the iron-box receiver.”²⁰

Professor Bell continued:

“Only a few days later another notable event in the history of the electric speaking telephone occurred. Articulate speech was, for the first time, transmitted and received between places that were separated by miles of space. I recall three experiments that were made in Canada, during the first two weeks of August, 1876. In all three of these experiments a membrane telephone was used as a transmitter, and the iron-box telephone as a receiver; and the membrane telephone was located in the office of the Dominion Telegraph Company, in Brantford, Ontario. The iron-box receiver was, in one experiment, located in the town of Paris, about eight miles from Brantford, the battery, however, being in Toronto, a distance of 68 miles from Paris. In another experiment the receiver was in Mount Pleasant, about five miles from Brantford; and in the third experiment, the receiver was placed on the veranda of my father’s house at Tutelo Heights, a distance, I suppose, of three or perhaps four miles from Brantford.

“In the first experiment alluded to, the membrane telephone with (the) triple mouthpiece was placed in the Dominion Telegraph Company’s office in Brantford, under the charge of Mr. Griffin, who was, if I remember rightly, either the manager or operator there. As my father told me he would be unable to be present on account of an engagement, I made arrangements with my uncle, Professor David C. Bell, to go to the Dominion office at an appointed hour, and recite into the membrane telephone. I also requested him to provide some singers, who should sing a three-part song into the triple mouthpiece. I then drove to the town of Paris—eight miles from Brantford—and attached the iron-box receiver to one of the lines leading to Brantford. The battery that operated the instruments was—as I have already said—in Toronto. I had provided electromagnets having coils of different resistance, which could be interchangably used in the telephones employed. Low-resistance coils were first tried. The moment I placed my ear against the diaphragm of the iron-box

²⁰ Ref. (2), p. 121.

receiver, I heard bubbling and crackling sounds, similar to those I had observed on the New York loop experiment, made July 12, 1876, on the lines of the Atlantic and Pacific Telegraph Company. Mixed up with this storm of noises, I could plainly perceive the voices of the speakers and singers in Brantford, in a faint, far-away sort of manner. I then telegraphed to Brantford by another line; and asked Mr. Griffin to substitute an electro-magnet with coils of high resistance for the low-resistance one he had been using. While he was doing this, I made a similar change in the coil of the iron-box receiver. The experiments were then resumed. The disturbing noises still continued, but the vocal sounds, in place of being faint and far away, became so loud and clear that familiar sentences were understood, and I could even recognize the voices of the different speakers and singers. One voice sounded so like my father's that I telegraphed to Brantford to ascertain whether it could possibly be his, for I had understood that he could not be present at the time. He was there, however, and it was his voice that I had heard. . . .

"This, I believe, was the first time words and sentences spoken in one place were transmitted by electrical means and successfully reproduced in another place many miles away."²¹

A notice of these experiments appeared in the *Scientific American* of September 9, 1876, in an article entitled, "The Human Voice Transmitted by Telegraph."²²

But this was a demonstration of telephonic transmission in one direction only. When it became necessary to convey information from the receiving end of the wire to the sending end, this had to be accomplished by telegraphing over another wire. Until a sustained conversation, in both directions alternately, had been carried on, the complete practicability of the telephone as a means of oral communication between distant points remained to be proved.

This forward step was taken on October 9, 1876, in the United States. About the first of that month, Professor Bell began to devote his attention mainly to the speaking telephone, subordinating multiple telegraphy. In July, he and Watson had made thin iron patches of different sizes which they attached to the diaphragms of membrane

²¹ Ref. (2), pp. 122, 123.

²² Ref. (12).

telephones. Comparative tests had shown that the larger the patch, the louder and more distinct was the tone. So, early in October, Professor Bell had Mr. Watson make two new instruments resembling the Centennial membrane telephones except that upon each membrane was glued a thin, circular sheet of iron almost as large in diameter as the membrane itself. Finding no difficulty in carrying on a sustained conversation by means of these instruments over a line connecting two rooms in the house at No. 5 Exeter Place, Boston, Bell determined to test them upon a real line. This he did on the evening of the same day, using a telegraph line owned by the Walworth Manufacturing Company and extending from their office in Boston to their factory in Cambridgeport, a distance of about two miles. Professor Bell remained at the Boston end of the line and Mr. Watson went to Cambridgeport. The results were very satisfactory and sustained conversation was, for the first time, carried on, backward and forward, upon the same line and by the same instruments used alternately for talking and listening between persons who were miles apart. To test the accuracy of transmission, Professor Bell and Mr. Watson each kept a record of the words transmitted and received.²³ The Boston *Daily Advertiser*, in its issue of October 19, 1876, published these two records in parallel columns in an article describing the experiment.²⁴ It shows that most of the conversation was transmitted with substantial accuracy. Two days after performing this test, Professor Bell communicated the results to the American Academy of Arts and Sciences and exhibited, in operation, the telephones that had been employed. A number of the members talked through them and Professor Bell was tendered the congratulations of the Academy upon his success.²⁵

Professor Bell's next step was to dispense with membrane diaphragms entirely, substituting for them diaphragms consisting solely of thin iron. These worked well, and the principle was incorporated in the construction of the so-called "box" telephones, the first of which were made in the latter part of October.²⁶

Realizing that it would be a good plan to conduct future tests over a real, out-of-doors line, Professor Bell made arrangements to

²³ Ref. (2), pp. 128, 129.

²⁴ Ref. (13).

²⁵ Ref. (2), p. 130.

²⁶ Ref. (2), p. 131.

connect his laboratory with a line that joined the Cambridge astronomical observatory with Boston.²⁷ This line was used during the day for transmitting time signals from the observatory clock to Boston for the regulation of timepieces of less exalted reputation. As the line was not used for this purpose at night, Professor Rogers of the observatory kindly tendered it to Professor Bell for his nocturnal tests. In order to avail himself of this offer, Professor Bell had a permanent wire run from his laboratory in Exeter Place to the establishment of Stearns and George, electricians, at No. 39 Pearl Street in Boston, where the observatory wire terminated, and from which point time service was distributed to various clockmakers' establishments in the city.²⁸

This gave Professor Bell the use of a real line some four or five miles in length; and thereafter he used it frequently, soon discovering that permanent-magnet telephones working without any battery gave better results over his "long line" than telephones containing electromagnets operated by a battery current on the main line. He had, of course, realized previously that, if desirable, he could energize his electromagnets by small batteries in the local circuits, independent of the main line.²⁹

Professor Bell was now eager to test his invention over a line of greater length than any hitherto employed. Accordingly, he arranged to make a trial on Sunday, November 26, 1876, over wires of the Eastern Railroad Company.

The account of the test, published in the *Boston Post* the following morning, read in part:

. . . "The latest experiments with the telephone were made yesterday over the wires of the Eastern Railroad, that day being selected because the trials would not then be interrupted by the ordinary business of the line. Professor Bell, President Rockwell, of the Eastern road, and wife, Miss Stearns, Mr. Morrison, and Mr. Hubbard, besides two telegraph operators, were the occupants of the Boston office. The instruments were arranged for about a twenty-mile test, consequently, Salem, about sixteen miles away, was the point at which a second telephone was fixed. Mr. Thomas A. Watson, assisted by the Salem operator, was in charge there. All those at the Boston end of the line held free

²⁷ Ref. (2), p. 131.

²⁸ Ref. (2), p. 132.

²⁹ Ref. (2), pp. 133, 134.

and easy conversation with the Salem office, even a whisper or a loud breath being distinctly heard at either end when given at the other. A remarkable instance of the extreme delicacy and faithfulness of the instrument was shown in the fact that when Mr. Hubbard first addressed the listener at the Salem end of the line, Mr. Watson instantly recognized his voice and called him by name before replying.

"Instead of grounding the wire at Salem that office was made a way-station, the through line extending to North Conway, 143 miles away. To give a more exacting test the Boston instrument was then attached to the Portland wire and the circuit made complete from Boston, through that city to Salem, a distance of about 200 miles. The voice could be heard with considerable clearness after having passed over this great distance, but owing to the unfit construction of the telephones for the duty required of them (they being arranged for about twenty miles), a distinctness was not attained which would allow a conversation to be carried on. Professor Bell is continually improving his invention, and he doubts not that he will ultimately be able to chat pleasantly with friends in Europe while sitting comfortably in his Boston home."³⁰

On January 25, 1915, Professor Bell, in New York, as the result of far-reaching modern improvements in telephony, including the development and application of loading coils and repeaters, was enabled to speak to Mr. Watson, in San Francisco, using a replica of his original telephone, his words being a repetition of those he had spoken on March 10, 1876: "Mr. Watson, come here; I want you." Professor Bell's death occurred in August, 1922. Had it been vouchsafed him to live only four years more, the development of transatlantic two-way telephony would have enabled him to witness the fulfillment of his prophecy of 1876.

On the Sunday following the first telephonic conversation between Boston and Salem, Professor Bell conducted tests from Boston over a railroad wire with Mr. Watson at North Conway, New Hampshire, where he had gone for that purpose. This was the first instance of the human voice being carried between points separated by more than one hundred miles of actual space.³¹

³⁰ Ref. (2), pp. 136, 137; Ref. (14).

³¹ Ref. (2), p. 137.

The spring of 1877 found Professor Bell, in response to invitations extended by representative groups of distinguished men in several cities, delivering a series of lectures, explaining the telephone, and exhibiting it in operation.

The first of this series was a public lecture before the Essex Institute in Lyceum Hall, Salem, on February 12, 1877.* Bell's lab-

*At a meeting of the Essex Institute, held at its rooms, Salem, Mass., U. S. A., February 19, 1877, the following resolutions introduced by Mr. A. C. Goodell, Jr., were unanimously adopted:—

RESOLVED: That we tender our cordial thanks to Professor Alexander Graham Bell, and to his associate Mr. Thomas Augustus Watson of Salem, for the wonderful and profoundly interesting experiments so successfully performed by them at Lyceum Hall on the evening of the 12th instant; and to the Atlantic and Pacific Telegraph Company, who generously permitted the use of their wires between Salem and Boston; and to Miss Anastasia L. Molloy, who operated the telegraph on that evening.

RESOLVED: That the experiments we have witnessed satisfactorily demonstrate the feasibility of conveying articulate sounds by means of magneto-electricity; and we find that this method possesses advantages over the ordinary electric telegraph in the following particulars:

First—In the simplicity and cheapness of the mechanism employed.

Second—In dispensing entirely with batteries.

Third—In avoiding the necessity of employing skilled operators.

Fourth—In the apparently great motive force of the magneto-electric currents employed and (according to the evidence exhibited by Professor Bell) in the fact that resistance is, by this means, so far overcome or avoided as to encourage the belief that, practically, no difficulty may be expected from that source in the longest circuits.

Fifth—In the rapidity of communication by the telephone and in the ease with which it insures accuracy by admitting of instantaneous vocal repetition from either end of a telephonic line.

RESOLVED: That the discovery that the vibrations of a conducting membrane or plate, set in motion by the human voice, can be so delicately and forcibly communicated to a corresponding membrane at the opposite end of an electric circuit, as to produce articulate sounds of exactly the same timbre, quality, pitch and relative strength appears to us one of the most marvelous discoveries of the Age; and the practical embodiment of this discovery, in the telephone, constitutes a most curious and remarkable invention; and we deem it especially noteworthy that these were not accidental, but the result of profound study of the science of acoustics, and a consequent inference that currents of electricity might be made to vary in intensity in the exact ratio that air varies in density when affected by sound.

RESOLVED: That we deem it a signal honor to have been privileged to witness the first public operation of this wonderful instrument, at a meeting a report of the proceedings of which was sent abroad as the first public message by the Telephone.

RESOLVED: That we are gratified to learn that these experiments are to be repeated in Salem, and to them as at once instructive and astonishing we invite the attention of the public.

RESOLVED: That these resolutions be communicated to Professor Bell and to Mr. Watson by the Secretary, and offered to the press.

A true copy from the records,

GEORGE M. WHIPPLE,

Secretary.

oratory in Boston was connected with the Hall by a wire of the Atlantic and Pacific Telegraph Company. Mr. Watson operated the telephone in Boston and his articulation was audible to the audience in Salem. For this exhibition, permanent magnet telephones with metallic diaphragms were employed and there was no battery in the line. So two of the outstanding characteristics of the modern telephone receiver had already been adopted.⁸²

Concerning this lecture, the *Boston Globe*, in its issue of February 13, 1877, stated:

"This special by telephone to the *Globe* has been transmitted in the presence of about twenty, who have thus been witnesses to a feat never before attempted—that is, the sending of a newspaper despatch over the space of eighteen miles by the human voice—and all this wonder being accomplished in a time not much longer than would be consumed in an ordinary conversation between two people in the same room."⁸³

These Salem exhibitions attracted wide publicity in the newspapers of the United States and were also noticed in the *Daily News* and the *Athenæum* of London, England.⁸⁴

On April 3, 1877, Professor Bell tried his telephones upon a telegraph line from Boston to New York, Mr. Watson, as usual, being stationed at the Boston end of the wire. Concerning this experiment the *Boston Daily Globe*, on April 5, stated:⁸⁵

"New York, April 4.—Professor A. Graham Bell made an experiment with his telephone, over the Atlantic and Pacific Telegraph Company's wires, between Boston and New York, last night; the professor, who was in this city, communicating with his assistants in Boston. The experiment was a great success. Everything said by the professor's assistants was plainly heard by those in attendance here, the conversation being carried on at the ordinary rate of talking."⁸⁶

The next notable lecture and exhibition was given in Music Hall, Providence, Rhode Island, on April 5, 1877, before an audience of

⁸² Ref. (2), p. 148.

⁸³ Ref. (15).

⁸⁴ Ref. (2), p. 150.

⁸⁵ Ref. (2), p. 151.

⁸⁶ Ref. (18).

about two thousand people. A pole was erected near the platform and telephones were arranged in different parts of the hall so that Professor Bell, with the aid of a switch on the platform, could connect the wire leading to Boston with any of them. By means of this arrangement, said Bell, "loud musical effects could be heard all over the hall."³⁷

Then a group³⁸—one might truthfully say a galaxy*—of Boston citizens extended to Bell an invitation to give an exhibition of the telephone in their city, in response to which he gave three lectures in Music Hall, Boston, early in May.

Early in April, a company of distinguished men † in New York invited Professor Bell to lecture in Chickering Hall of that city; this he did on three successive days in May.³⁹ Professor Bell's lectures brought him the first pecuniary returns from his invention of the telephone. Despite the inroads which they made upon his time, he found opportunity during May to make an improvement which brought his receiving instrument into a form that began to resemble the modern receiver in external appearance. For the first time, he made a telephone having its permanent magnet contained within a cylindrical

³⁷ Ref. (2), pp. 151, 152.

* The invitation was signed by Benjamin Pierce, Perkins Professor of Astronomy and Mathematics, Harvard College; Joseph Lovering, Hollis Professor of Mathematics and Natural Philosophy, Harvard College; E. N. Horsford, formerly Rumford Professor and Lecturer on the Application of Science to the Useful Arts, Lawrence Scientific School, Harvard University; Henry W. Longfellow, formerly Smith Professor of the French and Spanish Languages, and Professor of Belles Lettres, Harvard College; George B. Emerson, Fellow of the American Academy; Oliver Wendell Holmes, Parkman Professor of Anatomy, Medical School of Harvard University; Charles W. Eliot, President of Harvard University; Alexander H. Rice, Governor of the Commonwealth of Massachusetts; Nehemiah Gibson, Alderman of the City of Boston; Frederick O. Prince, Mayor of the City of Boston; William F. Warren, President of Boston University; John D. Runkle, Professor of Mathematics, Massachusetts Institute of Technology; Charles Francis Adams, formerly United States Minister Plenipotentiary to Great Britain; Wolcott Gibbs, Rumford Professor and Lecturer on the Application of Science to the Useful Arts, Lawrence Scientific School, Harvard University; and Edward C. Pickering, Director and Phillips Professor of Astronomy at the Observatory, Harvard University.³⁸

³⁸ Ref. (2), pp. 196, 197.

† F. A. P. Barnard, President of Columbia College; Howard Crosby, Chancellor of New York University; Henry Morton, Stevens Scientific School; E. L. Youmans, Editor, *Popular Science Monthly*; Cyrus W. Field, of Atlantic Cable fame; Thos. T. Eckert, President, Atlantic and Pacific Telegraph Company; A. M. Mayer, Stevens Scientific School; William Orton, President, Western Union Telegraph Company; J. S. Newberry, School of Mines, Columbia College; C. F. Chandler, Professor of Chemistry, College of Physicians and Surgeons; H. D. Noyes, Professor of Aural Surgery, Bellevue College; and Jno. W. Draper, Professor of Chemistry, New York University.³⁹

³⁹ Ref. (2), p. 153.

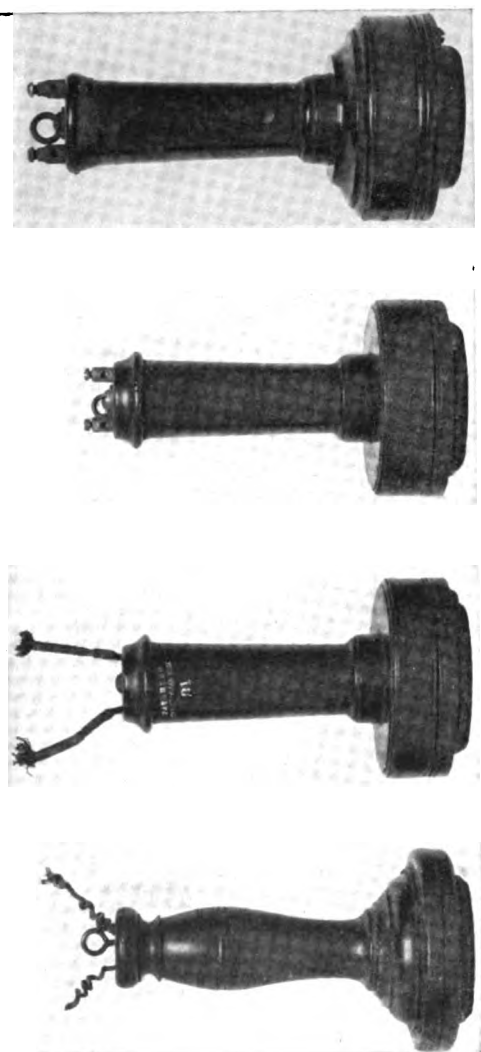


FIG. 7.—The First Four Commercial Styles of Hand Telephone Receivers. These receivers were all made in 1877, and are arranged in chronological order from left to right. All four types had wooden cases, black walnut being first employed. Mahogany was substituted in the second style. Single-pole permanent magnets were used and the diaphragms were of ferro-type iron. In the first three types, a coil of insulated wire was placed on the end of the permanent magnet; in the fourth type, the coil was placed on a soft iron pole-piece which was attached to the end of the permanent magnet. Speech currents, passing through this wire coil, varied the attraction of the permanent magnet for the diaphragm, causing the latter to vibrate and produce sound waves in the air corresponding to the speech currents.

case small enough to be grasped conveniently by the hand.⁴⁰ One of the early forms of hand telephone was subsequently or thereabouts styled the "butter-stamp," due to its resemblance to that implement of the dairy. The butter-stamp telephone is shown at the left in Figure 7, which represents the first four commercial forms of wooden hand telephones.

On July 11, 1877, occurred the wedding of Alexander Graham Bell to Mabel, the daughter of the Hon. Gardiner Greene Hubbard.⁴¹ Bell and his bride sailed from New York for Europe on or about August 4, 1877, remaining abroad for more than a year.⁴² While sojourning in England, he delivered a lecture, October 31, 1877,⁴³ before the Society of Telegraph Engineers at London. At the close of the lecture, Professor Abel, the president of the society, said that he should be "glad to hear the opinions of men eminent for their knowledge of physical science, of whom there were many in the room."⁴⁴ Mr. Latimer Clark then proposed a vote of thanks to Mr. Bell, and made some remarks in which he said that, since his connection with the society, there had never been a subject brought before them so interesting or so important as the one of which they had just heard, or one which would mark a greater epoch in the history of electricity. Mr. W. H. Preece seconded Mr. Clark's proposition, and in the course of his remarks spoke of Mr. Bell's allusion to the fact that expectancy sometimes led him to anticipate what was said through his early telephone. Mr. Preece said that he himself had recently exhibited the telephone before a very large audience including many learned men. He selected "one of the leading scientific men of the day" and placed the telephone in his hand, expecting to hear from his lips some words of special wisdom. The sage shouted through the telephone, "Hi diddle diddle—follow up that!" Then putting the telephone to his ear for the response, he stated with great satisfaction, "He says—'The cat and the fiddle.'" The person who was supposed to have made the answer was fifty miles away. The next day Mr. Preece met him and asked him if he understood the "Hi diddle diddle." The man said, "No, I asked him to repeat."⁴⁵

While he was in England, Professor Bell prepared a prospectus

⁴⁰ Ref. (2), p. 155.

⁴¹ Ref. (7), p. 123.

⁴² Ref. (2), p. 158.

⁴³ Ref. (2), p. 157.

⁴⁴ Ref. (2), p. 196.

⁴⁵ Ref. (2), p. 196.

designed to awaken the interest of a group of business men in promoting the use of the telephone. This document, written at Kensington, England, on March 25, 1878, a time when the telephonic art and business were as yet undeveloped, indicates such remarkable prophetic vision of its possibilities that it is quoted here substantially in its entirety:

"It has been suggested that at this, our first meeting, I should lay before you a few ideas concerning the future of the Electric Telephone, together with any suggestions that occur to me in regard to the best mode of introducing the instrument to the public.

"The telephone may be briefly described as an electrical contrivance for reproducing in distant places the tones and articulations of a speaker's voice, so that conversation can be carried on by word of mouth between persons in different rooms, in different streets, or in different towns.

"The great advantage it possesses over every other form of electrical apparatus consists in the fact that it requires no skill to operate the instrument. All other telegraph machines produce signals which require to be translated by experts, and such instruments are therefore extremely limited in their application, but the telephone actually speaks, and for this reason it can be utilized for nearly every purpose for which speech is employed. . . .

"At the present time we have a perfect network of gas-pipes and water-pipes throughout our large cities. We have main pipes laid under the streets communicating by side pipes with the various dwellings, enabling the members to draw their supplies of gas and water from a common source.

"In a similar manner, it is conceivable that cables of telephone wires could be laid underground, or suspended overhead, communicating by branch wires with private dwellings, country houses, shops, manufactories, etc., etc., uniting them through the main cable with a central office where the wires could be connected as desired, establishing direct communication between any two places in the city. Such a plan as this, though impracticable at the present moment, will, I firmly believe, be the outcome of the introduction of the telephone to the public. Not only so, but

I believe, in the future, wires will unite the head offices of the Telephone Company in different cities, and a man in one part of the country may communicate by word of mouth with another in a distant place.

"I am aware that such ideas may appear to you Utopian and out of place, for we are met together for the purpose of discussing not the future of the telephone, but its present.

"Believing, however, as I do that such a scheme will be the ultimate result of the telephone to the public, I will impress upon you all the advisability of keeping this end in view, that all present arrangements of the telephone may be eventually realized in this grand system. . . .

"In conclusion, I would say that it seems to me that the telephone should immediately be brought prominently before the public, as a means of communication between bankers, merchants, manufacturers, wholesale and retail dealers, dock companies, water companies, police offices, fire stations, newspaper offices, hospitals and public buildings, and for use in railway offices, in mines and (diving) operations.

"Agreements should also be speedily concluded for the use of the telephone in the Army and Navy and by the Postal Telegraph Department. Although there is a great field for the telephone in the immediate present, I believe there is still greater in the future.

"By bearing in mind the great object to be ultimately achieved, I believe that the Telephone Company can not only secure for itself a business of the most remunerative kind, but also benefit the public in a way that has never previously been attempted."⁴⁶

After his return to America, Professor Bell patented a number of inventions pertaining to electrical subjects.⁴⁷ Notable among these was the first "wireless" telephone, although the principle and the apparatus were quite different from those now used in radio transmission and reception. Bell's "wireless" telephone* utilized the well-known fact that the electrical resistance of crystalline selenium is affected by light, and that the diminution in resistance produced by

⁴⁶ Ref. (19), p. 89.

⁴⁷ Ref. (2), p. 190, *et seq.*

* U. S. Patent No. 235,199, December 7, 1880; "Apparatus for Signaling and Communicating, called 'Photophone.'"

illumination is proportional to the intensity of the light. At the focus of a parabolic reflector, he placed a selenium cell and connected it in a circuit with a battery and a telephone receiver. He also invented a transmitting apparatus which, upon being spoken to, caused the intensity of a beam of light, directed from a distance so as to fall upon the parabolic reflector, to vary in a manner proportional to the variations in the density of the air during the utterance of a sound. Thus the strength of the electrical current passing through the telephone receiver was caused to vary in a similar manner and the telephone produced a facsimile of the sound. With this photophonic apparatus, Professor Bell transmitted articulate speech a distance of about five hundred yards. Listening at the receiver, while his associate Mr. Sumner Tainter, spoke, he heard the words "Mr. Bell, Mr. Bell, if you hear what I say, come to the window and wave your hat." A tender light is shed upon Professor Bell's reason for not pursuing this work further.

In a letter which General Carty received from Mrs. Bell shortly after the death of her husband, she wrote:

"I verily believe that the reason Dr. Bell did not follow up his invention of the photophone"—or radiophone, as it became afterward—"the reason he did not follow that up, and the reason he took up aviation instead was that I could not hear what went on over the radiophone but that I could see the flying machine."

General Carty, referring to this letter, has said:

"It was a very touching letter and reminds me of what happened on his great day of triumph when Bell talked across the continent to Washington and when he received the congratulations of the Chief Magistrate of our Nation. Mrs. Bell was there and Bell, with a poignant sadness, looking toward his wife, said to me, 'And to think that she has never heard through the telephone.'"⁴⁸

Professor Bell was the recipient of many honors. Shortly after the merit of his telephone invention became known, the French government created him an Officer of the Legion of Honor and bestowed on him the Volta prize of 50,000 francs which was founded by the

⁴⁸ Ref. (11).

first Napoleon in 1802, about the time of the visit of Alessandro Volta to France, revived by the Emperor Napoleon III and continued under the Republic.⁴⁹ The American Institute of Electrical Engineers honored him with its presidency in 1891. His medals and honorary degrees are given in a footnote below.*

Shortly after Professor Bell's return to America, he began to relinquish to others the task of improving the telephone and developing the apparatus needed for use with it. Throughout his life he maintained a sustained interest in scientific matters covering a wide range of subjects.

At various times there have been published rumors of Dr. Bell's dislike for the telephone. These have been set at rest, once and for all, in a letter from Mrs. Bell, written from their summer home, Beinn Bhreagh, near Baddeck, Nova Scotia, shortly after his death, which read in part:

⁴⁹ Ref. (2), p. 201.

* List of Medals awarded to Alexander Graham Bell.⁵⁰

Centennial Exposition, Philadelphia, gold medal for speaking telephone (1876), gold medal for visible speech (1876).

Royal Cornwall Polytechnic Society, the James Watt silver medal for the telephone (1877).

Massachusetts Charitable Mechanics Association, gold medal for the telephone (1878), gold medal for visible speech (1878).

Society of Arts, London, Royal Albert silver medal for his paper on the telephone (1878).

République Française Exposition Universelle Internationale, Paris, gold medal for the telephone and a silver medal (1878).

Society of Arts, London, Royal Albert silver medal for his paper on the telephone (1881).

The Karl Koenig von Wuerttemberg gold medal.

Society of Arts, London, Royal Albert gold medal for his invention of the telephone (1902).

John Fritz gold medal (1907).

Franklin Institute of Philadelphia, Elliott Cresson gold medal for the electrical transmission of speech (1912).

David Edward Hughes gold medal and a silver medal (1913).

American Institute of Electrical Engineers, Thomas Alva Edison gold medal (1914).

Among the honorary degrees⁵¹ conferred on Alexander Graham Bell were:

Doctor of Laws: Illinois College (1881); Harvard College (1896); Amherst College (1901); Saint Andrew's University (1902); Edinburgh University (1906); Queen's University, Canada (1908); George Washington University (1913); Dartmouth College (1914).

Doctor of Philosophy: National Deaf-Mute College (now Gallaudet College) (1880); Würzburg University (1882).

Doctor of Science: Oxford University (1906).

Doctor of Medicine: Heidelberg, Germany (1886).

⁵⁰ Ref. (1).

⁵¹ Ref. (1).

"There are few private houses more completely equipped with telephones than ours at 1331 Connecticut Avenue (Washington, D. C.), and there was nothing that Mr. Bell was more particular about than our telephone service here (Baddeck). For nearly all of the thirty-five odd years we have been here he saw personally to its proper working. We never could have come here in the first place or continued here, but for the telephone which kept us in close touch with doctors and neighbors and the regular telegraph office. . . . Mr. Bell did like to say in fun, 'Why did I ever invent the telephone?' but no one had a higher appreciation of its indispensableness or used it more freely when need was—either personally or by deputy—and he was really tremendously proud of it and all it was accomplishing. . . . I shall always be thankful that the telephone worked so well that last day—serving its father so loyally."⁵²

At Baddeck, Nova Scotia, Alexander Graham Bell's life ended on August 2, 1922. His body was laid at rest on the summit of a near-by hill. Practical extensions of telephony and of the radio art (itself made possible by the telephone) continue to bring distant peoples more and more within the sound of one another's voices. When the last trammel is lifted from the amicable discussion of questions affecting the relations and well-being of races and nations, in the hearing of millions of men and women in whatever part of the earth they may be, who shall say that future pilgrims to his last resting place will not pay tribute to his memory as one of the greatest contributors that ever lived toward the realization of peace on earth and the universal brotherhood of man?

⁵² Ref. (20).

CHAPTER IV

THE BELL PATENTS: THEIR OWNERSHIP AND HOW THEY WERE ATTACKED

THE informal partnership between Bell, Hubbard, and Sanders was corroborated by a written agreement dated February 27, 1875, which, however, did not alter the previous understanding between the parties; namely, that Mr. Hubbard and Mr. Sanders should each furnish one-half of the money that Bell needed to carry on his experiments and to obtain patents covering his inventions, and that the three men should own the patents equally.¹

This written agreement did not mention the telephone. Its basis was that "the said Bell has invented certain new and useful methods and apparatus for telegraphing."² This language, construed in the light of the fact that both Mr. Hubbard and Mr. Sanders believed that the real value of Bell's work lay in the multiple telegraph, raised a question as to the ownership of his telephone patents, concerning which Dr. Bell has said:

"My understanding always was that the speaking telephone was included in the inventions that belonged to the Messrs. Hubbard and Sanders from the autumn of 1874, but I found at a later period that they had not had this idea, which might account for the little encouragement I received to spend time on experiments relating to it. Even as late as 1876, when the telephone was an assured success, Mr. Hubbard generously offered to relinquish to me all right and title to that invention, as he was inclined to think it was outside our original understanding."³

But Bell took the position that the telephone was included. Truly, this original partnership was a gentlemen's agreement! It did provide, however, that, upon the patents which it comprehended proving of value, a company should be organized to own and control them and

¹ Ref. (21), pp. 134, 135.

² Ref. (21), p. 136.

³ Ref. (21), p. 136.

that each of the three partners should receive one-third of the stock of that company.⁴

This was done through the appointment of Mr. Hubbard as trustee. A contract had been made with Mr. Watson in September, 1876, which provided that at first he should devote half of his time, and later all of it, to working on the development of Bell's inventions. For this he was to receive wages of three dollars a day and a one-tenth interest in all the patents when the company was organized. This interest of Mr. Watson's was now recognized when the Bell Telephone Company, Gardiner G. Hubbard, Trustee, was formed.⁵

On February 2, 1878, the New England Telephone Company, a Massachusetts Corporation (not the present New England Telephone and Telegraph Company), acquired from Mr. Hubbard, as trustee, territorial rights, under Bell's four patents,* for the New England States.⁶ On July 20, 1878, the rights in these patents for the rest of the country were assigned by Mr. Hubbard, as trustee, to a new corporation, the Bell Telephone Company.⁷ These two interests—one covering the New England States, the other the remainder of the United States—were soon united by purchase; and on March 20, 1879, the New England Telephone Company and the Bell Telephone Company both assigned to a new corporation, the National Bell Telephone Company, their rights under two of Bell's patents †—namely, those covering his harmonic telegraph system and the receiving instrument designed for use with it.⁸

The American Bell Telephone Company was chartered on March 19, 1880,⁹ and acquired, by assignment and licenses, all patent rights belonging to the Bell interests previously existing.¹⁰

For more than a year after the issue of Bell's fundamental patent (U. S. No. 174,465, March 7, 1876), no one, publicly at least, disputed

⁴ Ref. (21), p. 137.

⁵ Ref. (21), p. 138.

* U. S. Patent No. 161,739, April 6, 1875.

U. S. Patent No. 174,465, March 7, 1876.

U. S. Patent No. 178,399, June 6, 1876.

U. S. Patent No. 186,787, Jan. 30, 1877.

⁶ Ref. (21), p. 141; Ref. (86), p. 218.

⁷ Ref. (21).

† U. S. Patent No. 161,739, April 6, 1875.

U. S. Patent No. 178,399, June 6, 1876.

⁸ Ref. (21), p. 146.

⁹ Ref. (86), p. 218.

¹⁰ Ref. (21), pp. 148, 149.

his claims to originality, but it was not long before a serious attempt was made to override his patent rights and to challenge the novelty and comprehensiveness of his invention. The formidable antagonist which made this attack was the Western Union Telegraph Company—already national in its scope, with an extensive wire plant and a large number of commercial offices in hotels, railway stations, and other public places. In the fall of 1876 Mr. Hubbard had offered to sell the telephone invention to the Western Union Telegraph Company for \$100,000, but his offer had been refused. By the summer of 1877, however, the Western Union Telegraph Company appeared to have become satisfied that the telephone was likely to assume great importance. After Bell's patent * for his telephone invention had been issued, patent applications for various forms of speaking telephones and transmitters were filed in the United States Patent Office by different individuals. Prominent among these were Elisha Gray of Chicago, Thomas A. Edison of Menlo Park, New Jersey, and Amos E. Dolbear of Somerville, Massachusetts.

The Gold and Stock Telegraph Company, a subsidiary of the Western Union Telegraph Company, in September, 1877, entered into an agreement with Dolbear in which he undertook to apply for a patent on his telephone and to assign it to the first named company when and if issued.¹¹ In December, 1877, the Western Union Telegraph Company organized the American Speaking Telephone Company, which, in the same month, acquired the right to use all of Gray's patents and applications in so far as these might relate to speaking telephones.¹² At the end of May, 1878, the Western Union Telegraph Company entered into an agreement with Edison whereby they acquired control of the latter's telephone inventions.¹³

The Gold and Stock Telegraph Company, which was already conducting a telegraph business, was made the agent of the American Speaking Telephone Company and was to have the exclusive management of the latter's telephone business.¹⁴

The telephone instruments which the Western Union interests made and used at this time were receivers constructed on the plans of Gray and Phelps, and transmitters constructed on the plans of

* U. S. No. 174,465, March 7, 1876.

¹¹ Ref. (78), p. 314 (Dolbear Agreement).

¹² Ref. (78), p. 129; Ref. (86), p. 193 (Deposition of Samuel M. Taylor).

¹³ Ref. (86), p. 8 (Bill of Complaint); Ref. (79), p. 58.

¹⁴ Ref. (86), p. 204 (Deposition of Samuel M. Taylor).

Edison and Phelps.¹⁵ George M. Phelps was the superintendent of the Western Union Telegraph Company's New York shop.* The Western Union, through its subsidiaries, thus entered the telephone field in defiance of the patent rights of Bell at a time when the Bell interests had put out only a few thousand telephones.¹⁶ By 1879 the Gold and Stock Telegraph Company had manufactured and was controlling the use of many thousands of telephones and had established telephone exchanges in the city of New York and elsewhere.

To meet this attack the Bell Telephone Company, on September 12, 1878, brought a suit in equity in the Circuit Court of the United States, District of Massachusetts, against Peter A. Dowd for infringement of Bell's patents Nos. 174,465 and 186,787. Dowd was an agent of the Western Union Company, engaged in putting out telephones in Massachusetts. The Western Union Company assumed the defense of this suit, and in the course of its trial substantially all of the alleged defenses that were adduced in subsequent litigation involving the Bell patents were brought out. Among these was the claim of priority of invention for Gray, Edison, Dolbear, and others; the claim that Bell's telephone, as described in his principal patent (U. S. No. 174,465), was not capable of transmitting articulate speech; and the claim that Bell's invention had been anticipated in a long list of prior publications, including descriptions of a so-called "telephone," devised by Philipp Reis.

After the facts had been fully brought out in evidence in the Dowd suit, Mr. George Gifford, the counsel of the Western Union Telegraph Company, became convinced that Mr. Bell would prevail and advised a settlement of the suit.¹⁷ Negotiations between representatives of the Bell and the Western Union interests resulted in the execution of a contract, dated November 10, 1879. The settlement was based upon the admission by the Western Union Company that Bell was the inventor of the telephone and that his patents were valid and covered the various forms of telephones which had been put out by the Western Union Telegraph Company, including transmitters employing carbon contact elements. It also provided that the Western Union Company

¹⁵ Ref. (79), p. 503.

* Some of the telephone apparatus which the Western Union interests used was manufactured in the telegraph company's own shop in New York City and some in the factory of the Western Electric Manufacturing Company in Chicago.

¹⁶ Ref. (80).

¹⁷ Ref. (79).

should retire from the telephone business; that the Bell Company was granted licenses under all the telephone inventions which the Western Union Company had already acquired or which it might acquire during the term of the contract; that the Bell Company was to buy the telephones which the Western Union Company or its subsidiaries had made and the telephone exchanges which they had established. This agreement added to the Bell System 56,000 telephones in 55 cities. Under the terms of this settlement, the Bell interests agreed to pay to the Western Union Company, for a term of seventeen years, twenty per cent of all rentals or royalties from licenses or leases of speaking telephones used in the United States.¹⁸ The final decree in the Dowd suit was approved by Judge Lowell on April 4, 1881. This marked the end of the Western Union attack.

As the merit and value of the Bell invention continued to become more and more apparent, there were many unauthorized persons who attempted to make, use, and sell telephones, and, as so often happens after an important patent is issued, many claimants were subsequently brought forward in whose behalf it was sought to prove that they, before Bell, had conceived the idea of the telephone and had made instruments which conveyed speech over a wire electrically. In some instances these claimants attempted to obtain patent rights for themselves, and in others their claims were urged as grounds by which it was sought to set aside the Bell patents. Despite the fact that the Western Union Company had conceded that Bell was the inventor of the telephone and had granted to the Bell Company licenses under the telephone inventions which it owned of Gray, Edison, Dolbear, Phelps, and others, subsequent litigants (see Appendix A) repeatedly urged that the work of Gray and others had anticipated the work of Bell and sought thereby to invalidate Bell's patents. As Judge Thomas J. Morris observed in one of the telephone cases, "The purpose of a patent is to prevent everybody but the one who owns it from using that invention."¹⁹ It therefore became necessary for the Bell Company to sue infringers of the Bell patents. In all, there were about six hundred suits involving the Bell patents, only a small proportion of these, however, going to final hearing. In Appendix A will be found references to the more notable of these suits with brief summaries giving information as to the circumstances which sur-

¹⁸ Ref. (86).

¹⁹ Ref. (82).

rounded each and as to its final disposition. In many of these cases, the same claims were brought up repeatedly; but, to avoid burdening this chapter, the contentions of a few of the rival claimants will, in the following pages, be presented under the name of the claimant, the text being extracted from the decisions of the courts in order to present a picture of the nature of some of the contentions and the opinions of the courts in disposing of the issues.

In reviewing this mass of litigation, at a later date, in the suit brought to annul the Berliner patent (*q. v.*), Mr. Justice Brewer, of the United States Supreme Court, said *:

“Bell claimed to be the pioneer in this matter of telephonic communication. His claim was disputed, and out of that dispute came the most important, the most protracted litigation which has arisen under the patent system in this country. For years this litigation was pending in the trial courts, subsequently brought to this court, and finally decided in 1888. So great was this litigation, so immense the volume of testimony, and so important the rights involved, that it is the only case in the history of this court to which an entire volume of our reports is devoted (126 U. S.). The argument was protracted through weeks, and the case was held under consideration for a year, and finally decided by a closely divided Court.”

Philipp Reis

Reis devised an electrical telephone by means of which he unsuccessfully attempted to transmit speech.²⁰ His apparatus was repeatedly brought forward as an anticipation of Bell. Why it failed is set forth clearly in the extracts below.

The Circuit Court of the United States, District of Massachusetts,²¹ speaking through Judge Lowell, said as follows:

“An apparatus made by Reis, of Germany, in 1860, and described in several publications before 1876, is relied on to limit the scope of Bell’s invention. Reis appears to have been a man of learning and ingenuity. He used a membrane and electrodes for transmitting sounds, and his apparatus was well known to

* 167 U. S. 260.

²⁰ *Vide*, p. 232.

²¹ Ref. (4).

curious inquirers. The regret of all its admirers was that articulate speech could not be sent and received by it.

"The deficiency was inherent in the principle of the machine. It can transmit electrical waves along a wire, under very favorable circumstances, not in the mode intended by the inventor, but one suggested by Bell's discovery; but it cannot transmute them into articulate sounds at the other end, because it is constructed on a false theory, and the delicacy of use required to make it perform part of the operation is fatal to its possible performance of the other part.

"A Bell receiver must be used to gather up the sound before the instrument can even now be adapted to a limited practical use. It was like those deaf and dumb pupils of Professor Bell, who could be taught to speak but not to hear. That was all, but it was enough. A century of Reis would never have produced a speaking telephone by mere improvement in construction."

The Circuit Court of the United States, Eastern District of Louisiana,²² in its opinion of May 31, 1886, said:

"That Reis made great strides towards the discovery of the great fact or law subsequently announced in the fifth claim of Bell does not admit of doubt. That he failed to reach it is equally beyond question. . . .

"His apparatus appears to have been devised in the attempt to transmit speech by electricity, but the attempt was an acknowledged failure. His apparatus, under the influence of the voice or other sounds, simply broke the circuit at each principal vibration with a frequency corresponding to the pitch of the sounds."

Finally, Mr. Chief Justice Waite, delivering the opinion of the Supreme Court of the United States,²³ in the October term, 1887, said:

"It is not contended that Reis had ever succeeded in actually transmitting speech, but only that his instrument was capable of it if he had known how. He did not know how, and all his experiments in that direction were failures. With the help of Bell's later discoveries in 1875 we now know why he failed. . . .

"It was left for Bell to discover that the failure was due not

²² Ref. (22).

²³ Ref. (23), pp. 542, 544.

to workmanship but to the principle which was adopted as the basis of what had to be done. He found that what he called the intermittent current—one caused by alternately opening and closing the circuit—could not be made under any circumstances to reproduce the delicate forms of the air vibrations caused by the human voice in articulate speech, but that the true way was to operate on an unbroken current by increasing and diminishing its intensity. This he called a vibratory or undulatory current, not because the current was supposed to actually take that form, but because it expressed with sufficient accuracy his idea of a current which was subjected to gradual changes of intensity exactly analogous to the changes of density in the air occasioned by its vibrations. Such was his discovery, and it was new. Reis never thought of it, and he failed to transmit speech telegraphically. Bell did, and he succeeded. Under such circumstances it is impossible to hold that what Reis did was an anticipation of the discovery of Bell. To follow Reis is to fail, but to follow Bell is to succeed. The difference between the two is just the difference between failure and success. If Reis had kept on he might have found out the way to succeed, but he stopped and failed. Bell took up his work and carried it on to a successful result.”

Meucci

Judge Wallace, in the opinion of the Circuit Court of the United States, Southern District of New York,²⁴ July 19, 1887, summarized the work of Meucci as follows:

“According to Meucci’s story, while he was at Havanna, employed as a machinist and decorator of a theatre there, and in the year 1849 or 1850, he discovered how to obtain the transmission of words by means of conducting wire, united with several batteries to produce electricity, and gave his discovery the name of the ‘Speaking Telegraph.’

“In 1850 he came to this country, and took up his residence at Clifton, Staten Island, where he has ever since resided. He was engaged in various kinds of business, particularly candle-making, and the manufacture of paper from vegetable fibre, and at one time had a brewery.

²⁴ Ref. (24).

"He states that soon after coming here he resumed his experiments with the telephone; that before 1860 he had good working instruments; and before 1865 had instruments which embodied the essentials of the modern magneto instruments.

"These instruments he asserts were known to his friends; were in use at his house before and during the years 1864 and 1865, and subsequently. He describes them from his memory. The originals are not in existence. He states that in 1860 he thought his invention sufficiently perfected to introduce it, and about that time applied to his friend Bendelari, who was going to Italy, to try to get assistance to perfect the invention, and bring it into use.

"He says that he felt anxious to have his invention first appear from his old home, and thought Bendelari would be able to bring the invention out there; and he therefore gave a pretty full description of it to Bendelari, and also about this time published the fact that he had made the invention in an Italian newspaper published in New York called *Echo L'Italienne*. He states that after this, until 1871, from time to time, he experimented to make improvements in his invention, but made no particular improvements after 1864 or 1865. He says that in 1871 he found that his wife, during his illness, had, without his knowledge, sold all the instruments and devices he had used in his experiments in sound telegraphy, except some bobbin(s), a part of a permanent magnet, and some fragments of pasteboard, which he subsequently found, to a dealer in second-hand articles.

"In the latter part of 1871 he entered into an agreement with three of his Italian friends, by which they became copartners in the business of perfecting and introducing his invention. The written agreement, bearing date December 12, 1871, is produced, and recites the business of the copartnership as that of 'making and trying all the necessary experiments for the accomplishment of the transmission of the human voice through electric wires invented by the aforesaid Antonio Meucci.'

"These parties immediately took steps looking to the procurement of a patent, consulted Mr. Stetson, a patent expert and solicitor, and, under his supervision an application for a caveat *

* A description of an invention that is not fully perfected, filed in the Patent Office.

was prepared, and was filed in the patent-office, December 28, 1871. Soon thereafter Meucci consulted again with Mr. Stetson, with a view of making an application for a patent for the invention, but Mr. Stetson discouraged the attempt. Upon the application of Meucci, the caveat was renewed in December, 1882, and again in December, 1883. It is not claimed that Meucci made any essential improvements upon his invention subsequent to the time he obtained the caveat, but, as has been said, he states himself that he made none after 1865.

"Such in brief is Meucci's own history of his invention. There is no reason to doubt that for many years prior to 1865, and from that year until he applied for the caveat, he had been experimenting with telephonic and electrical apparatus with a view of transmitting speech, and during this time had convinced himself that he had made interesting discoveries, which might eventually become useful ones. To this extent he is corroborated by the testimony of a number of witnesses. But the proofs fail to show that he had reached any practical result beyond that of conveying speech mechanically by means of a wire telephone. He doubtless employed a metallic conductor as a medium for conveying sound, and supposed that by electrifying the apparatus or the operator he could obtain a better result.

"That he did not believe he had accomplished anything of practical commercial utility is a reasonable inference from the fact that he did not communicate his invention to those who would have been likely to appreciate it, and assist him in perfecting and introducing it to the public. Between 1859 and the time of his application for a caveat he filed many applications for patents for other inventions. During the years 1859, 1860, and 1861 he was in close business and social relations with William E. Ryder, who was interested in his inventions, paid the expenses of his experiments, and, in connection with others whom he introduced to Meucci, invested a considerable amount of money in Meucci's inventions, and their use in business enterprises.

"He was a constant visitor at Meucci's house, lived near him, and seems to have been his closest personal friend and business adviser.

"Their intimate relations continued until 1867, when Ryder became satisfied that Meucci's inventions were not sufficiently

practical or profitable to devote more time and money to them, and their intimacy ceased, although as late as in 1871 he interested himself for Meucci to dispose of some of his inventions. During all these years, according to the testimony of Mr. Ryder, he never heard from Meucci, or anybody else, of Meucci's telephone.

"In 1864 and 1865 David H. Craig was a partner with Meucci and Ryder in the paper manufacture.

"He had been intimately associated with others in telegraph inventions and patents, and his interest in such matters must have been known by Meucci. He never heard, from Meucci or otherwise, that Meucci had invented or was experimenting with the telephone.

"The caveat itself is sufficient to indicate that he had reached no practical result. There is no reason to doubt that his application contained the best description of his invention which he was then able to give.

"Before consulting Mr. Stetson, Meucci prepared a description of his invention, intending to make an application for a patent. After consulting Mr. Stetson, he concluded to make application for a caveat only. With the aid of an interpreter, and the manuscript containing the description, Mr. Stetson prepared the formal application. After it had been prepared by Mr. Stetson, it was sent by him to Meucci, and returned by the latter with amendments to be inserted in it. It is sufficient to say that the application does not describe any of the elements of an electric speaking telephone. Its opening statement refutes the possibility that Meucci understood the principle of that invention. Meucci states that he employs:

" 'The well-known conducting effect of continuous metallic conductors as a medium for sound, and increases the effect by electrically insulating both the conductor and the parties who are communicating.'

"As originally expressed by Mr. Stetson, it contained this statement:—

" 'The system on which I propose to operate consists in isolating two persons, separated at considerable distances from each other, by placing them upon glass insulators, employing glass, for

example, at the feet of the chair or bench on which each sits, and putting them in communication by means of a telegraphic wire.'

"As amended pursuant to Meucci's instructions, this statement was qualified as follows:—

" 'It may be found practicable to work with the person sending the message insulated, and with the person receiving it in free electrical communication with the ground. Or these conditions may possibly be reversed, and still operate with some success.'

"It is idle to contend that an inventor having such conceptions could at that time have been the inventor of the Bell telephone.

"The application does, however, describe a mechanical telephone, consisting of a mouthpiece and earpiece connected by a wire. A letter written by Mr. Stetson of the date of January 13, 1872, is in evidence, and is important as confirmatory of the conclusion that beyond this the invention was only inchoate. This letter was written to Meucci when the latter was in communication with Mr. Stetson in reference to obtaining a patent for the invention. In this letter Mr. Stetson, in substance, advised Meucci that his invention was not in a condition to patent; telling him that it was 'an idea giving promise of usefulness,' and the proper subject of a caveat, but requiring many experiments to prove the reality of the invention.

"Without adverting to other evidence tending to indicate that Meucci was merely an experimentalist who had not produced anything new in the art of transmitting speech by electricity, it suffices to say that his pretensions are overthrown by his own description of the invention at a time when he deemed it in a condition to patent, and by the evidence of Mr. Stetson.

"The evidence leaves the impression that his speaking telegraph would never have been offered to the public as an invention if he had not been led by his necessities to trade on the credulity of his friends; that he intended to induce the three persons of small means and little business experience, who became his associates under the agreement of December 12, 1871, to invest in an invention which he would not offer to men like Ryder and Craig; and that this was done in the hope of obtaining such loans and assistance from them as he would temporarily require."

Elisha Gray

Gray was Bell's closest rival in point of time. Like Bell, Gray had been working in the field of multiple telegraphy. The application for Bell's patent (No. 174,465) was filed in the United States Patent Office on February 14, 1876. A few hours later, on the same day, Elisha Gray had filed in the Patent Office a caveat claiming the art of transmitting speech electrically.

The nature of Gray's claim* and the serious charges that were made in his behalf may be understood from the following extract from the opinion of the Supreme Court of the United States, handed down in 1888:²⁵

"Another objection to Bell's patent . . . is, that his application as originally filed in the Patent Office did not contain his present fourth claim, or any description of the variable resistance method, and that all which now appears in the specification on that subject, including the fourth claim, was surreptitiously interpolated afterwards.

"Bell's application was filed February 14, 1876, and afterwards, during the same day, Elisha Gray filed a caveat, in which he claimed as his invention 'the art of transmitting vocal sounds or conversations telegraphically through an electric circuit,' and in his specification described the variable resistance method. The precise charge now made in the printed brief of Mr. Hill is, that 'Mr. Bell's attorneys had an underground railroad in operation between their office and Examiner Wilbur's room in the Patent Office, by which they were enabled to have unlawful and guilty knowledge of Gray's papers as soon as they were filed in the Patent Office,' and 'that an important invention, and a claim therefor, were bodily interpolated into Bell's specification, between February 14, 1876, and February 19, 1876, by Pollok, in consequence of the guilty knowledge which the latter already had of

* As already stated in the early part of this chapter, Gray, Edison, Dolbear, and others had filed patent applications for various forms of speaking telephones and transmitters, after Bell's patent had issued. These caused the so-called "Speaking Telephone Interferences," which occupied the attention of the Patent Office for more than ten years, and resulted in sustaining all of Bell's claims. Anyone interested in a very complete discussion of the claims of Gray, Edison, Dolbear, and others, in support of their applications should consult the decisions of the Patent Office in these interferences.

²⁵ Ref. (23).

the contents of Gray's caveat before the declaration of interference with Gray on February 19th.'

"So grave a charge, made in so formal a manner, is entitled to careful consideration. It involves the professional integrity and moral character of eminent attorneys, and requires us to find from the evidence that after Bell swore to his application on the 20th of January, 1876, and after the application thus sworn to had been formally filed in the Patent Office, an examiner, who got knowledge of the Gray caveat put in afterwards, disclosed its contents to Bell's attorneys; that they were then allowed to withdraw the application, change it so as to include Gray's variable resistance method over Bell's signature, and over the *jurat*, and then restore it to the files, thus materially altered, as if it were the original; and all this between February 14 and February 19.

"Although much stress was laid in argument on the fact that what purported to be a certified copy of the specification of Bell, as found in the file wrapper and contents printed in the Dowd case, differed materially from the patent, the cause of these differences has been explained in the most satisfactory manner, and we entertain no doubt whatever that the specification as now found in the patent is precisely the same as that on which the order to issue was made. If any alterations were made it was all done before February 19, and the fair copy which is now found on the files of the Office is precisely as it was when the order for the patent was granted. Not a shadow of suspicion can rest on anyone growing out of the misprint of the specification in the Dowd case.

"All that remains, therefore, on which to rest this serious charge is, that in a paper handed by Bell to George Brown, of Toronto, describing his invention, and which was intended to be used in England to secure a British patent, what is now claimed to be an interpolation in the American application is not to be found. It is but right to say that during the whole course of the protracted litigation upon the Bell patent, no argument was ever presented based on this discrepancy until the brief of Mr. Hill was filed in this court on the 18th of January, 1887, six days before the argument in these appeals was begun. So far as we are advised nothing had ever before occurred in the cases that

seemed to make it necessary to prove when the variable resistance method or the fourth claim was put into the American application, or why it was left out of the paper handed to Brown. It seems always to have been assumed until the cases got here, that because it was in the American patent it was rightfully there. Certainly there is nothing in the pleadings in any of the cases to direct attention to the materiality of this fact.

"A comparison of the paper handed Brown with the American application shows that they differ in more than thirty different places besides those which relate to the variable resistance method and the fourth claim. The differences are generally in forms of expression, thus indicating that one was written after the other and evidently for the purpose of securing greater accuracy. The paper handed Brown was clearly a rough draft and not a fair copy, for the record shows that it bore on its face the evidence of many erasures and interlineations. Bell says in his testimony that he began writing his specification in September or October, 1875, and wrote and rewrote it a number of times, finally adopting that mode of expression which seemed to him the best to explain his invention and the relation which one portion bore to another. He visited Brown in Canada in September and again in December, 1875. The arrangement was made between them on the 29th of December, at this last interview, by which Brown was to interest himself in getting out British patents. Other inventions besides the telephone were included in the contract entered into for that purpose.

"Bell returned to Boston on the 1st of January, and immediately set himself to work to complete his specification. He had it done so that it was taken to Washington by Mr. Hubbard about the 10th of that month, and delivered to Pollok and Bailey, the attorneys. It was then examined by the attorneys, found correct, and a fair copy made and returned on the 18th to Bell in Boston for his signature and oath. It was signed and sworn to in Suffolk County, Massachusetts, January 20, and immediately returned to the attorneys. Afterwards Pollok met Bell in New York, and it was again gone over with care by the two together. No change whatever was made in it at that time, and Pollok took it back with him to Washington.

"On the 25th of January, 1876, Bell met Brown, who was

then on the way to England, in New York. It is now assumed that the paper which Brown took to England was handed to him then, and because the variable resistance method and the fourth claim were not in that, it is argued that they could not have been in the American specification at that time. But no one has said when the paper was actually handed to Brown. Bell says he cannot tell, but that it must have been after he made his contract with Brown on the 29th of December. As the American specification was signed and sworn to five days before the interview with Brown on the 25th of January, and the paper of Brown differs from it in so many particulars besides that now in question, it would seem to be clear that the paper was a copy of some former draft which Bell had made—possibly one taken to Canada in December—and not of that which was perfected afterwards. As the specification which had been prepared and sworn to was a fair copy, without erasures or interlineations, the fact that the paper handed Brown was not a fair copy would imply that it was not intended to be an exact transcript of the other. At any rate, the bare fact that the difference exists under such circumstances is not sufficient to brand Bell and his attorneys and the officers of the Patent Office with that infamy which the charges made against them imply. We therefore have no hesitation in rejecting the argument. The variable resistance method is introduced only as showing another mode of creating electrical undulations. That Bell had had his mind upon the effect of such a method is conclusively established by a letter which he addressed to Mr. Hubbard on the 4th of May, 1875, and which is found in the Dowd record, introduced into the Overland case by stipulation.

“Its insertion in his final draft of his specification is another proof of the care with which his work had been done.”

Drawbaugh ²⁶

Daniel Drawbaugh was a mechanic living at Milltown, in Cumberland County, Pennsylvania. He contended that long before Bell had formed a mental conception of the telephone and had perfected it, he (Drawbaugh) had not only made the same invention but had perfected improvements in organization and detail which Bell never

²⁶ Ref. (25).

reached and which were only reached years afterward by the work of many other inventors in the same field of improvement.

Drawbaugh alleged that he commenced his experiments with the speaking telephone as early as 1866, and that, prior to or as early as 1867, he had made apparatus employing a teacup as the transmitter through which speech could be transmitted feebly and incoherently; and that as early as the birth of his son Charles, in 1870, he had so progressed that his wife, confined to her bed, could by listening with one of his instruments hear the words spoken by him in the other instrument in a distant part of the house, although whispered words could not be accurately heard.

He said that the body of his transmitter was a porcelain teacup; the diaphragm, of membrane; the electrodes, two copper disks interposed in the circuit, the upper one connected to the diaphragm by a wire so as to vary its pressure upon pulverized charcoal interposed between the disks; his receiver, a tin can without top or bottom, having a membrane stretched over one end, connected by a tense cord to an armature supported on a spring and arranged close to the poles of an electromagnet in the electric circuit.

Said the U. S. Circuit Court, Southern District of New York,²⁷ on December 1, 1884, speaking through Judge Wallace:

"According to the theory of the defendants, therefore, as early as February, 1875, Drawbaugh had not only distanced Bell in the race of invention, but also Gray and Edison, and had accomplished practically all that has since been done by a host of other inventors.

"The case for the defendants must stand or fall by this theory. . . . It is either true that Drawbaugh had long been treading his solitary path of investigation and experiment in poverty and obscurity, but had perfected his work when the inventions of other explorers were in embryo, or his story is an ingenious fabrication. . . . If the defence is a fabrication, many disinterested witnesses have contributed innocently to give it color and strength, but Drawbaugh has deliberately falsified the facts."

A cloud of nearly two hundred witnesses was brought in this attempt to disprove that Bell was the first inventor. It developed that a hard-headed old farmer, on being told by Drawbaugh that he had

²⁷ Ref. (25).

a machine by which he could talk across the Atlantic Ocean, advised him to "try it first in talking across the Yellow Breeches Creek."

Drawbaugh described himself as "one of the greatest inventive geniuses of this age, who has spent the greater part of an active life conceiving and producing, as the result of the conceptions of an unusually fertile brain, a score of useful, ingenious machines, and devices."

He was a skillful and ingenious mechanic but none of his inventions was sufficiently meritorious to prosper vigorously. Said the court:

"Drawbaugh . . . was not only untutored, but he was isolated by his associations and occupations from contact with men of advanced science; he had narrow opportunities for instruction, and few incentives for profound research. . . .

"He was a tyro in electrical science, essaying the most difficult work of the electrician. It is almost incredible that the subtle intellectual discoveries which were a closed book to the ablest electrician could have been reached by a smatterer in science." . . .

During the trial of the case Drawbaugh said:

"I don't remember how I came to it. I had been experimenting in that direction. I don't remember of getting at it by accident either. I don't remember of any one telling me of it. I don't suppose any one told me."

Said the court:

"An inventor can hardly forget the process of thought by which a great intellectual conception germinates and matures into the consummate achievement; but Drawbaugh's memory is a blank. . . . He never attempted to exhibit it outside of his own shop to prove that it would transmit speech at a distance of even a quarter of a mile. . . . He did not attempt to avail himself of opportunities for demonstrating his invention and bringing it to the notice of friends who were peculiarly qualified to appreciate, and were favorably circumstanced to assist him. . . . He understood himself to be an experimenter with telephones or phonographs, but not the inventor of the speaking telephone."

Drawbaugh knew about the Reis telephone and he had seen Bell's exhibit at the Centennial in 1876. The court said:

"There is enough here to explain Drawbaugh's declarations to his neighbors about the talking-machine he was inventing, and to excite the curiosity of the community. A careful reading of the proofs renders it easy of belief that the witnesses who testify about casual visits to his shop, which occurred many years before their testimony was delivered, and to cursory tests of his instruments on those occasions, have confused the fragmentary and incoherent articulation of such an apparatus, with the hearing of distinct words and sentences. When witnesses undertake—as many of them do—to give the exact words or sentence heard in the instrument five or ten years before, when their attention was not called to the subject afterwards, no hesitation is felt in rejecting such statements as utterly incredible. It may be charitably inferred that such a witness has confused his recollection with more recent impressions."

The opinion concludes as follows:

"Succinctly stated most favorably for the defendants the case is this: One hundred witnesses, more or less, testify that on one or more occasions, which took place from five to ten years before, they think they saw this or that device used as a talking machine. They are ignorant of the principle and of the mechanical construction of the instruments, but they heard speech through them perfectly well, and through one set of instruments as well as the other. This case is met on the part of the complainants by proof that the instruments which most of the witnesses think they saw and heard through were incapable of being heard through in the manner described by them; and further, that the man who knew all about the capacity of his instruments never attempted to use them in a manner which would demonstrate their efficiency and commercial value, but, on the contrary, for ten years after he could have patented them and for five years after they were mechanically perfect, knowing all the time that a fortune awaited the patentee, and with no obstacles in his way, did not move, but calmly saw another obtain a patent, and reap the fame and profit of the invention. Without regard to other features of the case it is sufficient to say that the defense is not established so as to remove a fair doubt of its truth; and such doubt is fatal."

On appeal, the Supreme Court of the United States said:²⁸

"We do not doubt that Drawbaugh may have conceived the idea that speech could be transmitted to a distance by means of electricity and that he was experimenting upon that subject, but to hold that he had discovered the art of doing it before Bell did would be to construe testimony without regard to 'the ordinary laws that govern human conduct,' . . . Without pursuing the subject further we decide that the Drawbaugh defence has not been made out."

Dolbear

Amos E. Dolbear, Professor of Physics of Tufts College, near Boston, Massachusetts, was another alleged inventor of a telephone.* An infringement suit was brought against him by The American Bell Telephone Company. The nature of his claims may be understood by the following extract from Mr. Justice Gray's opinion:²⁹

"The mode or apparatus by which Bell effects his purpose is by using an electromagnet in the transmitter, and another electromagnet in the receiver. But the essence of his invention consists not merely in the form of apparatus which he uses, but in the general process or method of which that apparatus is the embodiment.

"Dolbear likewise uses an electromagnet in the transmitter; and both his method and his apparatus, as is admitted in his own affidavit, are substantially like Bell's, until he comes to the receiver. For the magneto-receiver, Dolbear substitutes a condenser-receiver, consisting of two thin metal diaphragms or disks, of about the size and thickness of those used in an ordinary Bell telephone, separated by a very thin air space, one or both disks connected with the conducting wire, and the speaking disk, if not so connected, otherwise charged with electricity; so that, as the varying currents flow into and out of this condenser, the two disks attract one another more or less strongly, and thereby vibrations are set up which correspond to the vibrations of the original sound.

"The main difference on which the defendants rely is that

²⁸ Ref. (23).

* See page 209.

²⁹ Ref. (83).

Bell uses what is called dynamic electricity, producing by its motion an electric current; while Dolbear, in his receiver, uses what is called static electricity, producing, while at rest, electrical attraction. . . . It does not appear to us to be important to determine whether, in scientific exactness, the varying influences of static electricity may properly be called currents; or whether the two properties of electricity differ in kind and in substance, or only in degree, or in the form of manifestation and application; or whether the force of the property which tends to make a fluid, when stationary, change its place and flow, is different in kind from that which it exerts when changing its place and flowing; in short, whether the power of the pressure of water in a reservoir is different in kind from water-power in a stream or current.

“Whatever name be given to the property, or the manifestation, of the electricity in the defendants’ receiver, the facts remain that they avail themselves of Bell’s discovery that undulatory vibrations of electricity can intelligibly and accurately transmit articulate speech, as well as of the process which Bell invented, and by which he reduced his discovery to practical use; that they also copy the mode and apparatus by which he creates and transmits the undulatory electrical vibrations, corresponding to those of the air; and that in the plate charged with electricity, which they have substituted for the magnetic coil in the receiver, the charge constantly varies in accordance with the principle which Bell discovered, and by means of the undulatory current caused by the process, and in the mode which he invented and patented. The defendants have therefore infringed Bell’s patent by using his general process or method, and should be restrained by injunction from continuing to do so; and it is unnecessary, for the purposes of this decision, to consider whether the defendants’ apparatus is a substantial equivalent of the plaintiff’s, or whether it is an improvement for which Dolbear might himself be entitled to a patent.”

Before leaving the Dolbear case, it seems fitting to quote the opening statement of Mr. Justice Gray’s opinion on account of its broad and general interest in connection with the patent law:

“Few legal rules have been oftener misunderstood and misapplied than the maxim that you cannot patent a principle. But

the confusion on this subject has been so effectually cleared up by the recent judgment of the Supreme Court, delivered by Mr. Justice Bradley, in *Tilghman v. Proctor*, 102 U. S. 707, that it will be sufficient for the purposes of this case to state the conclusions there announced. There can be no patent for a mere principle. The discoverer of a natural force or a scientific fact cannot have a patent for that. But if he invents for the first time a process by which a certain effect of one of the forces of nature is made useful to mankind, and fully describes and claims that process, and also describes a mode or apparatus by which it may be usefully applied, he is, within the meaning and the very words of the patent law, 'a person who has invented or discovered any new and useful art'; and he is entitled to a patent for the process of which he is the first inventor, and is not restricted to the particular form of mechanism or apparatus by which he carries out that process. Another person, who afterwards invents an improved form of apparatus, embodying the same process, may indeed obtain a patent for his improvement, but he has no right to use (the) process, in his own or any other form of apparatus, without the consent of the first inventor of the process."

The Government Case ⁸⁰

This was the last major offensive directed against the validity of the Bell patents. In July, 1885, after they had been sustained by a number of Circuit Court decisions, and after some of the earlier telephone cases had been appealed to the Supreme Court of the United States, certain hostile interests applied to the Attorney-General of the United States asking that suit be brought, in the name of the United States, to cancel the Bell patents, the applicants offering to furnish proofs that Mr. Bell was not the inventor of the telephone. As a result of this application, after numerous intermediate proceedings, a bill to cancel the Bell patents was filed in the name of the United States against The American Bell Telephone Company and Alexander Graham Bell, on January 13, 1887, in the Circuit Court of the United States for the District of Massachusetts. Before the taking of proofs in this case had been finished, the Bell patents had been sustained by the Supreme Court of the United States, and they

⁸⁰ Annual Report, A. B. T. Co., March 30, 1886.

had also expired by lapse of time. After the death of the counsel in charge of the case for the Government, in the summer of 1896, the case was practically abandoned by the Government.

The circumstances surrounding the beginning of this case were described at some length in the annual report to the stockholders of The American Bell Telephone Company, March 30, 1886, from which the following narrative is largely taken.

In 1883 there was organized the Pan Electric Telephone Company, with a capital of five million dollars, for which the ostensible basis of value was a group of patents, some of which related to telephones, of one Rogers. Its headquarters were in Memphis, Tennessee, which was also the home of several of its promoters.

The company had, apparently, so little to offer—the patents in question being perhaps the most palpable infringements upon the Bell patents that any one had hitherto attempted to rely upon—that it was for a time difficult to see what the promoters expected to accomplish, either in the establishment of a telephone business, or in starting a legal contest.

A number of well-known men, including two United States Senators, were on its board of directors. These men received large blocks of the capital stock for which they paid nominal sums of money. Subcompanies were formed, from which bonuses in cash were taken for the right to practice the Rogers inventions in different places, and blocks of the stock of these subcompanies appeared to have come to the promoters.

Early in 1884 the attorney of the Pan Electric Company was asked for an opinion on the Rogers patents. A man who said that his attention had been drawn to the stock of the Pan Electric Company wrote, as if for information, upon a matter of investment, but it appeared later that he was in the service of the Pan Electric Company and was therefore not interested in buying its stock but in selling it. The attorney of the Pan Electric Company replied upon the following day, giving what from its tone purported to be a professional opinion, to the effect that he had carefully examined the Rogers patents, and that he was clear that they in no way infringed the patents of Bell. Nothing contained in his letter indicated that he was interested deeply, as a stockholder, in the market value of the Pan Electric stock. Upon this opinion largely, it appeared, the bonuses were obtained from subcompanies and efforts were made to sell Pan Electric stock.

It should have been clear that the right to practice the Rogers inventions could have had no substantial value under any circumstances; for if the patents controlling the telephone business could have been declared void, the Pan Electric Company would only have been able to share the field with all comers, and the rights for which the bonuses and stock were taken would have been of wholly imaginary value. The opinion of the Pan Electric attorney about the Rogers patents was not shared, apparently, by his associates; for it was renounced by them at a subsequent hearing before the Secretary of the Interior when they squarely stated that, if Bell's patents were valid, the Rogers patents infringed them and they did not propose to contest that point.

The first way in which the influential names of the Pan Electric Company's officers were to be used was, therefore, in getting money for supposed rights which had no value; the second was to get the suits of the Bell Company against the Pan Electric Company and associates stopped.

The plan for accomplishing this latter purpose was as follows: In 1884 an attempt was made to get a statute passed by Congress authorizing the Government to bring suit to have patents vacated under certain circumstances. This measure passed the House, but it did not pass the Senate Committee on Patents.

Shortly, the attorney of the Pan Electric Company became Attorney-General of the United States, and other Pan Electric leaders occupied important government positions.

The next step was to ask the Attorney-General to order a suit brought to annul Bell's patents on the ground that he obtained them by fraud and that he was not the first inventor.

The Attorney-General declined to act, and, having left Washington temporarily, his next in office, within a day or two of his departure, received a similar request from an associate company of the Pan Electric Company, called the National Improved Telephone Company of New Orleans. Upon one day's examination that official decided that there was reason and authority for consenting, and he ordered the suit brought, not in Massachusetts, the home state of The American Bell Telephone Company, but in Memphis, Tennessee.

He placed in charge of the suit, with authority to proceed in the name of the Government, one man who was an officer of the Pan Electric Company, another who was a stockholder, and two associates. These men had a bill (printed beforehand in New Orleans) which

was immediately filed in Memphis. As soon as this Government suit was ordered, counsel for the Pan Electric Company appeared in Baltimore before Judge Bond, who was about to hear an application for injunction against that company, and asked for a postponement of proceedings on the ground that the Government suit was a valid objection to a preliminary injunction. This request, however, was not granted. It having been found, in Washington, that the action of the Department of Justice had been taken without reference for information to the Department of the Interior, the suit brought in Memphis was withdrawn. A new request was then preferred and sent to the Department of the Interior for information. The Secretary of the Interior gave a hearing lasting a week on the question of the Government suit. Apart from consideration of the merits of the questions involved, he advised that the Government had a right to bring such a suit and also that it should do so, apparently because there was an allegation of fraud involving officers of one of the departments, which, for some reason not explained, he thought could alone be investigated in a suit brought by the Government itself; but he advised that the Government should conduct its own case and at its own expense. Soon after this hearing the suit against the National Improved Telephone Company in New Orleans, an associate of the Pan Electric Company, was reached. Once more, their counsel appeared with the request that the case be postponed because the Secretary of the Interior had advised the Government to bring suit against the owners of the Bell patents, and that other cases ought not to be heard until that was decided.

The president of The American Bell Telephone Company, in his annual report of March 30, 1886, said in part:

“It is easy to understand the injury to the Bell interests that would follow if the United States Courts should refuse us all protection against infringement until the Government could try over again and determine all the questions relating to the priority of the telephone invention, which it has taken us eight years of arduous litigation to bring to their present condition of readiness for the Supreme Court.”

So grave and threatening was the situation for the owners of the Bell patents, that the president of The American Bell Telephone Company went to Washington for the purpose of placing the facts before

the President of the United States. An interview was arranged and the Chief Magistrate was told:

“that the present owners of the Bell patents had bought them in good faith, in the belief, which they still entertained, that they were properly obtained, and were valid; that on the strength of United States patents, and repeated decisions of the United States Courts in their favor, the parent company and its licensees had invested vast sums of money in putting this invention into use throughout the country; that the sum of fifty or sixty millions of dollars was now at stake in the business; that every issue which the Government was asked to raise, was already in the records of several cases that had been argued and passed upon by the United States Courts, which were already far on their way to the Supreme Court, on appeal . . .; that we had expended eight years of litigation, involving over fifty days of argument by the ablest counsel we could procure, the taking of over five thousand pages of testimony, and the expenditure of half a million of dollars; that our licensees could not but view with alarm the prospects of going once more over this expensive and tedious road, in the face of a suit brought by the Government at the instance of a company which they believed to be wholly speculative and irresponsible.

“It was shown that the programme of the Pan Electric Company was to get our suits stopped, and not tried, and to avail of official influence to get this accomplished, and it was explained how thoroughly our property could be destroyed without trial, could the existing suits be suspended while the Government suit was slowly making its way to a decision.”

The government adhered to the advice of the Secretary of the Interior and filed a bill against The American Bell Telephone Company and its licensees at Columbus, Ohio, before the judge who would also have heard the case had it been brought at Memphis. A plea to the jurisdiction was entered and the bill was dismissed and subsequently filed in the District of Massachusetts.

Writing in 1886, the president of The American Bell Telephone Company said, in his annual report to the stockholders:

“Regarding the newspaper agitation that has attended this Pan Electric exposure, it is proper to say that we have taken no

part in it, directly or indirectly. While it would have been wholly within our right to place all the information within our reach in the possession of the press, we felt that having adopted the course of going directly to the Government with the facts as we understood them, it was the proper course, at least under the then existing circumstances, to take no part in any discussion in the newspapers. Yet, it has been impossible to avoid a sense of outrage at the whole transaction, and the support it has received in official circles, which made it difficult to maintain silence, and we feel that this full statement of the matter is due to the stockholders."

As already stated, the case was finally abandoned after 1896. And so, after eight weary years of litigation, the last great attack on the validity of the Bell patents ended. The record was never printed.

These extracts from Court decisions have been given at some length with the thought that, by giving the reader, interested in modern telephony, an opportunity to read the language used in them, he can perhaps, better than in any other way, form a conception of the nature of the litigation that finally resulted in Alexander Graham Bell being fully sustained as the inventor of the telephone.

CHAPTER V

THE BEGINNING OF THE MICROPHONE TRANSMITTER

ONE of the most important forward steps in the telephone art, which followed shortly after Bell's inventions of the telephone and the variable resistance liquid transmitter employing a solid electrode immersed in a conducting liquid, was the discovery of the principle of the variable contact resistance transmitter using two solid electrodes in contact with each other. Two inventors, Emile Berliner and Thomas A. Edison, were prominently identified with this important improvement, which, thus far, has been indispensable in commercial telephony. Working at about the same time, they both recognized the possibility of producing a more powerful and practicable transmitter than the liquid transmitter of Bell, by means of variable resistance contact in a circuit, the variable resistance being so controlled by the motion of a voice-actuated diaphragm as to reproduce, in the electrical circuit, containing a battery, the characteristic form of the undulations due to the voice vibrations and thus enable articulate speech to be transmitted.

In 1876 Berliner, residing in Washington, D. C., became interested in the subject of the telephone, and, coming across Bell's patent, was fascinated by the brilliancy of the invention. Writing in April, 1879, he said:

"I commenced making experiments relating to the speaking telephone in January, 1877. Some time during that month one of the operators in the fire-alarm office in Washington, in showing me about the use of the Morse key, explained the importance of pressing the key down firmly upon its rest or base in order to insure the operation of the sounder promptly. He explained that if the key was not firmly pressed down, the sounder might fail to respond promptly and that was a reason why female operators were often objected to because they do not have sufficient strength to give a good contact between the key and its rest. It immediately occurred to me that if a variation of contact pressure between the circuit-closing key and its rest could produce a variation

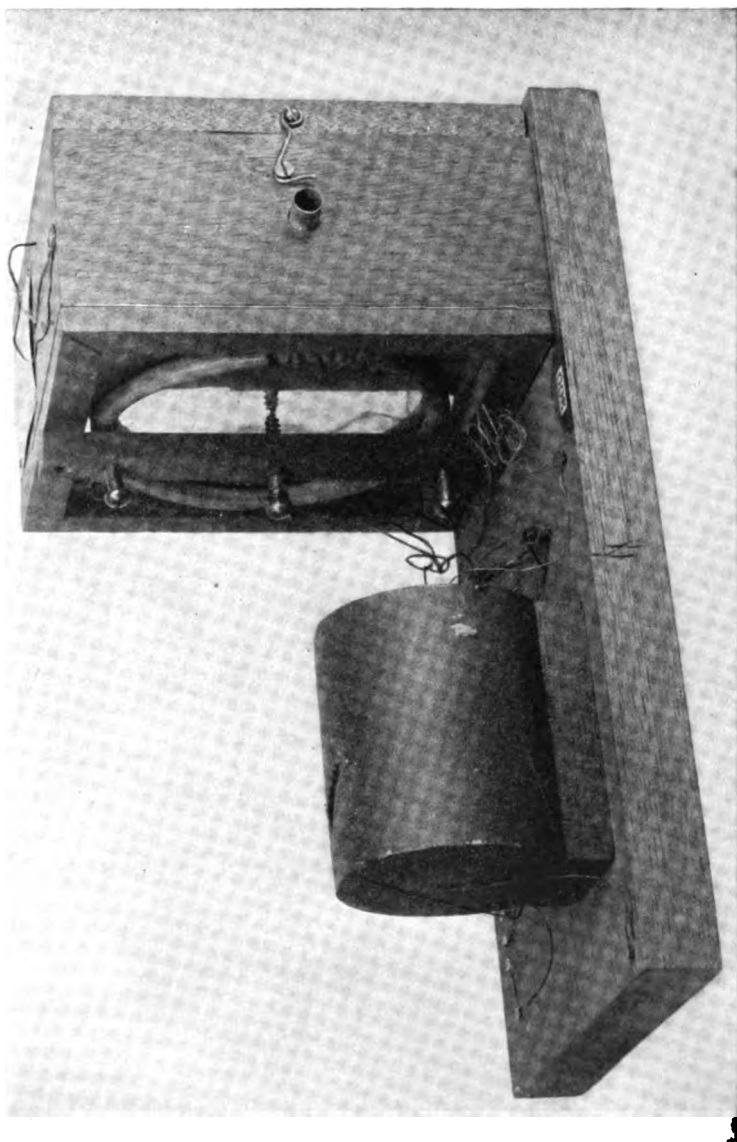


FIG. 8—Patent Office Model of Berliner's Telephone—1877. The induction coil is shown at the left.



in the current, then a varying pressure between the points of contact could be obtained by the vibration of one or both of them imparted to them by sounds or sound waves in the air in their neighborhood. I am unable to fix the exact time when this conception occurred to me but am certain it was in the month of January. I commenced experimenting immediately to see if my conception was correct."¹

He experimented in February and March and met with comparative success, considering the crude nature of his apparatus.

On April 14, 1877, Berliner filed, in the United States Patent Office, a caveat, drawn by himself, describing a variable pressure contact transmitter having metal electrodes which, he had discovered, could also be used as a telephone receiver without the use of a Bell magneto telephone.

Berliner's instrument (Fig. 8) consisted of a metallic diaphragm adapted to be vibrated by the sound waves uttered against it, having in contact with the center of the diaphragm either a metallic screw or a metallic ball on the point of a screw. The screw (or ball) and the diaphragm were placed in an electrical circuit so as to form electrodes in contact with each other. As the pressure between these electrodes was varied by the vibrations of the diaphragm under the influence of sound waves, the resistance at the joint was varied, being diminished or increased in proportion as the pressure between the electrodes was increased or diminished.

Concerning this discovery, Professor Charles R. Cross said:

"All that was really known regarding the subject under consideration at the date mentioned was that it was necessary to have a 'good contact,' that is, a firm pressure between two contact pieces in order not to cut down the current. . . .

"I know of no instrument in which the pressure was intentionally weakened in order to weaken the current, or in which there was any attempt to make use of this way of weakening or varying the current."²

The principle of the operation of microphonic contacts was made known to the scientific world by Professor David E. Hughes, in England, in May, 1878, while Berliner's application for a patent was pend-

¹ Ref. (26).

² Ref. (27).

ing in the United States Patent Office.* Professor Hughes first experimented with an electrical circuit containing a battery, a magneto-telephone receiver, and three nails, one connected to each pole of the battery, the circuit being completed by a third nail lying crosswise upon and in contact with the two already mentioned, which were otherwise disconnected. He also demonstrated the remarkable microphonic sensitivity of hard carbon contact points.

Concerning Professor Hughes's experiments with microphonic contacts, Mr. Spottiswoode, the president of the British Association, in an address of August, 1878, said:

"The microphone affords another instance of the unexpected value of minute variations—in this case of electric currents; and it is remarkable that the gist of the instrument seems to lie in obtaining and perfecting that which electricians have hitherto most scrupulously avoided, *viz.*, loose contact."³

The *Telegraphic Journal and Electrical Review*, July 1, 1878, stated:

"The microphone is a striking illustration of the truth that in science any phenomenon whatever may be turned to account. The trouble of one generation of scientists may be turned to the honour and service of the next. Electricians have long had sore reasons for regarding a 'bad contact' as an unmitigated nuisance, the instrument of the Evil One, with no conceivable good in it, and no conceivable purpose except to annoy and tempt them into wickedness and an expression of hearty but ignominious emotion. Professor Hughes, however, has, with a wizard's power, transformed this electrician's bane into a professional glory and a public boon. Verily, there is a soul of virtue in things evil."⁴

In 1877 Mr. Edison filed an application for a patent † on a variable pressure contact telephone transmitter having metal disk and plumbago film electrodes. In the same year he also applied for a patent on a transmitter utilizing a series of plumbago cylinders.‡ These applications waited fifteen years before the patents were issued on account

*Berliner's application filed June 4, 1877.

³ Ref. (28).

⁴ Ref. (29).

† U. S. Patent No. 474,230, issued May 3, 1892.

‡ U. S. Patent No. 474,231, issued May 3, 1892.



FIG. 9-A—Blake Transmitter—Closed.

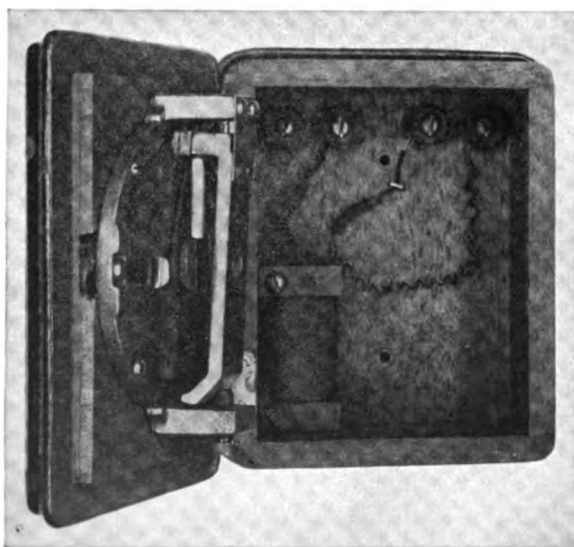


FIG. 9-B—Blake Transmitter with Door Open. The working parts of the instrument were contained in a walnut box. The door served as a mouthpiece and as a support for the operating parts which were attached to an iron casting mounted on the inside of the door. The induction coil may be seen in the lower left corner of the box.

of a protracted interference in the Patent Office. Early in 1878 he filed another patent application * for a compressed lamp-black carbon transmitter which operated to vary the pressure on the lamp black at each sound vibration, thereby causing electrical undulations, similar to the sound waves, in the transmitter circuit. This arrangement was employed between 1878 and 1883 in a commercial form of transmitter.

In 1878 Francis Blake, Jr., of Weston, Massachusetts, invented a variable contact transmitter in which a block of hard carbon was mounted on a stiff spring, and a bead of platinum mounted on a light spring was pressed against the carbon block. The spring bearing the platinum bead bore against the voice-actuated metallic diaphragm (Figs. 9-A, 9-B, 9-C). The microphonic contact occurred between the platinum bead and the hard carbon block. In adjusting the instrument the platinum bead and the carbon block were first brought into light contact with each other, and this was followed by forcing the spring bearing the platinum bead against the center of the diaphragm under considerable pressure from the stiff spring that supported the hard carbon block. The Blake instrument transmitted the voice very clearly, and it worked satisfactorily over short ranges. Blake's transmitter invention was patented in England, January 20, 1879,† but was not sealed until after his date of application for American patents. These patents (Nos. 250,126, 250,127, 250,128, and 250,129) were issued on November 29, 1881. The commercial form of the Blake transmitter, beginning late in 1878, rapidly displaced the Berliner and Edison types, and was extensively used for a long time as the Bell System standard.

On September 16, 1878, Henry Hunnings, a clergyman of Rothwell, County of York, England, applied for a British patent for a transmitter having a chamber of which the diaphragm formed one of the walls or electrodes, the other conducting electrode, which formed the opposite wall of the chamber, being fixed—that is, non-vibrating. The space between these electrodes was partially filled with pulverized “engine coke,” a light, porous, friable form of carbon, in order to secure a large number of points of microphonic contact. The Hunnings British application was sealed on December 24, 1878. Two United States patent applications were filed. The first, filed May 14, 1881, resulted in U. S. Patent No. 246,512, issued August 30, 1881.

* U. S. Patent No. 203,016, issued April 30, 1878.

† A British patent dates from the date of application.

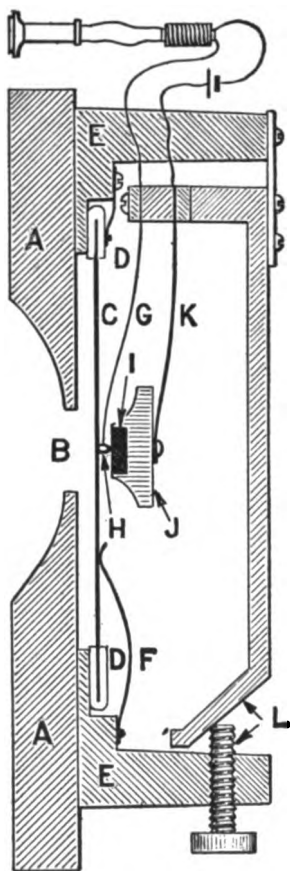


FIG. 9-C.—BLAKE TRANSMITTER: CROSS-SECTION OF WORKING PARTS

In door A, was orifice B, to permit acoustic waves to reach iron diaphragm C, the rim of which was covered by a soft rubber ring D, resting against the iron mounting frame E. At the rear of the diaphragm and pressing against it was the damping spring F, without which, the natural period of vibration of the diaphragm would have caused the transmitted sounds to be blurred. The light flexible spring G, resting against diaphragm C, bore the platinum bead H, which made microphonic contact with disk I, of hard carbon, set in the metal backing J, which was borne by the substantial spring K. The parts marked L provided means for adjusting the pressure at the microphonic contact between the carbon disk I and the platinum bead H. This contact was connected in series with a single cell of battery and the primary winding of the induction coil. The secondary winding of the induction coil was connected to the line and the receiver in series.

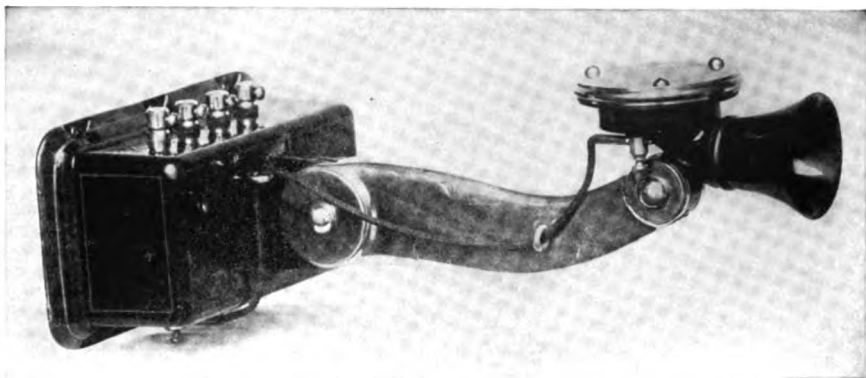


FIG. 10-A—"Long-Distance" Transmitter. One of several forms.

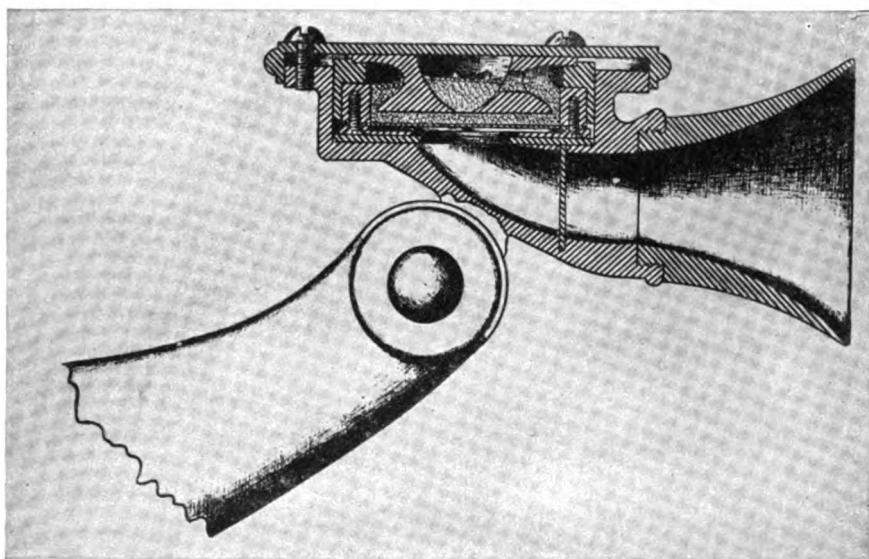


FIG. 10-B—Cross-Section of "Long-Distance" Transmitter. The horizontal diaphragm of thin platinum was tightly stretched and clamped firmly between two brass rings. A separator of varnished boxwood was employed to maintain the gold-plated upper electrode at the proper separation from the diaphragm. The space above the platinum diaphragm was filled with granular carbon into which the gold-plated electrode extended to a point about one-sixteenth of an inch above the diaphragm. A self-levelling device was provided so that the transmitter could be moved vertically through a range of several inches without disturbing the level of the diaphragm which it was important to maintain in order that the granular carbon should always remain evenly distributed. In this transmitter the mouthpiece first took the general form, later used in the solid back transmitter. These instruments were usually operated with three cells of Fuller battery.

It covered the use of "finely-divided carbon in a loose or free state." The second, filed September 30, 1881, resulted in U. S. Patent No. 250,250, issued November 29, 1881. It covered the use of any "finely-divided conducting material in a loose or free state." Both of these patents were purchased by The American Bell Telephone Company. The Hunnings transmitter, when at its best, produced a loud talk, but it worked intermittently.

Mr. Edison filed an application on February 19, 1886, for a patent which issued July 9, 1889 (U. S. Patent No. 406,567), covering the use in a transmitter of granules of carbonized hard coal. This was an important development, as granular carbon made from anthracite is still used in modern telephone transmitters.

In 1885 Bell engineers improved the Hunnings transmitter, re-designing it and using a horizontal diaphragm made of a thin sheet of platinum and a gold-plated electrode. Granular carbon was used between the diaphragm and the gold-plated electrode. This transmitter (Figs. 10-A, 10-B) gave favorable results when it was operating at its best; but, after protracted use, the large quantity of granular carbon which it contained produced an insensitive condition that materially lowered its effectiveness.

Several years of work were required to overcome this defect.

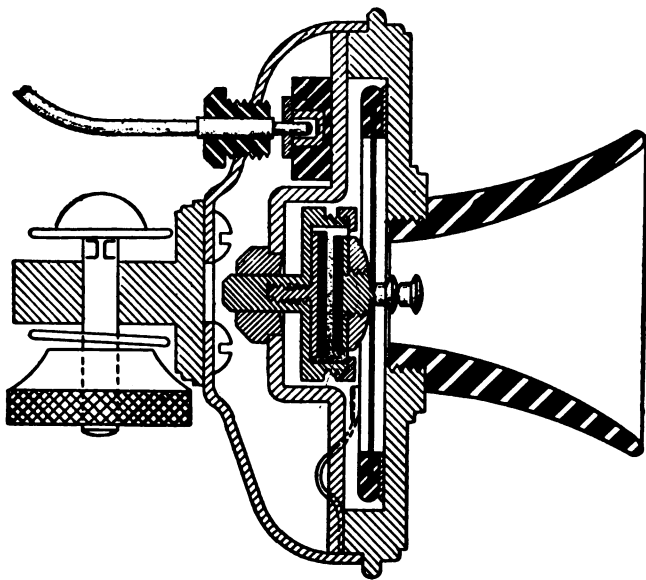


FIG. 11.—CROSS-SECTION OF "SOLID BACK" TRANSMITTER.

The problem was finally solved, in 1890, by Anthony C. White, a Bell engineer, who invented the "solid back" transmitter (Fig. 11). In this instrument, the vital element was the "button," so-called, which was a chamber containing granular carbon, partially filling the space between two electrodes, consisting of circular disks of carbon. One of these, the fixed electrode, was firmly and non-movably supported by the solid backing furnished by a stout metal frame, or bridge. The other was suspended so as to enable it to move forward and backward, in a piston-like manner, actuated by the motion of the diaphragm to which it was rigidly attached at the center of the latter.

The flexible suspension of the front, or movable, electrode was effected by attaching it to the periphery of the button by an annular ring of thin, selected mica. This served also to prevent the carbon granules from escaping from the button. Many substances, such as silk and paper, were tried experimentally before mica was finally selected. This transmitter proved so satisfactory in its operation that its general design has formed the basis of succeeding instruments, although several important improvements have been made and adopted since its invention. White's solid back transmitter patent was U. S. No. 485,311. The application was filed on March 24, 1892, and the patent issued on November 1, 1892.

The Berliner Patent Litigation

On November 17, 1891, a patent * was granted to The American Bell Telephone Company, as assignee of Emile Berliner, for a combined telegraph and telephone. This patent embraced a claim for the microphone. As mentioned on page 78, the application had been filed on June 4, 1877. The patent would have been issued long before, except for the interfering applications of Drawbaugh. Every attempt to obtain the Berliner patent was met by the statement of the Patent Office examiners that it was withheld for a possible interference. It was presumed by the American Company that the interfering party was Drawbaugh, and the attention of successive commissioners of patents was repeatedly called to documentary evidence in the Patent Office, proving that the Berliner invention was in public use for more than two years before Drawbaugh made application for patents. On October 28, 1891, upon evidence taken in a proceeding to which Drawbaugh was a party, the Commissioner of Patents finally rejected the

* U. S. Patent No. 463,569.

Drawbaugh application, saying, in a published decision, that "it is found that the improvement in controversy was in public use and on sale more than two years prior to the time when Drawbaugh filed his application for patent under consideration, and that for such reason he is not entitled to a patent therefor." A few days afterward, the Berliner patent was ordered to issue.⁵

In 1893 the Attorney-General of the United States instituted a suit to annul the Berliner patent. For that purpose the Government filed its bill of complaint in the Circuit Court of the United States for the District of Massachusetts against The American Bell Telephone Company and Emile Berliner on February 9, 1893. It charged particularly that the original application did not cover the microphone, but was only made to do so by unlawful amendments, that Berliner was not the original and first inventor of the microphone, and, above all, that the progress of the application in the Patent Office was wrongfully delayed.

In the course of the proceedings the brief or argument, which had been filed with the Attorney-General and on which he was asked to take action, was sent to the Interior Department and the Patent Office for consideration and report. The Commissioner gave the matter exhaustive examination, and said in conclusion:

"I do not believe that a suit to repeal this Berliner patent is justifiable."

This report was sent to the Honorable the Secretary of the Interior, who, in turn, sent it to the Attorney-General with a communication containing an expression of his own belief that Berliner's was the mind that made the invention covered by the patent, that the amendments complained of were made in due course, and that there were no extraordinary delays in the prosecution of the patent imputable to Berliner or his representatives. It was said at the time to have been without precedent for the Department of Justice to bring a suit to annul a patent without first obtaining, from the department of government from which the patent issued, an expression of opinion that the suit ought to be brought.⁶ The suit was argued in June, 1894, before the Circuit Court, and, on December 18, 1894, the Court

⁵ Annual Report, A. B. T. Co., March 29, 1892, p. 7.

⁶ Annual Report, A. B. T. Co., March 28, 1893, pp. 14, 15.

rendered a decision that the patent was void.⁷ An appeal was taken to the Circuit Court of Appeals, and on June 14, 1895, as of May 18, 1895, the Court rendered an opinion reversing the decree of the Circuit Court and ordering the bill to be dismissed.⁸ The government took an appeal to the Supreme Court of the United States.⁹ A decision was rendered affirming the decree of the Court of Appeals dismissing the bill, the opinion being filed on May 10, 1897.¹⁰

The United States Circuit Court of Appeals, in 1903, construed the Berliner patent (No. 463,569) as not infringed by transmitters which embodied the discoveries of the carbon electrode and the microphonic principle, and restricted it to cover only a variable contact resistance transmitter having metallic electrodes.¹¹ It is to be hoped that future researches may sometime supply a degree of knowledge of the nature of microphonic action which was beyond the purview of the scientific world at the time when these issues were matters of legal contention.

The Edison Carbon Telephone Patent

The annual report of The American Bell Telephone Company, March 28, 1893, stated:

"This year we are able to report that Edison's application for a patent for the carbon telephone has also finally met with success and resulted in patent No. 474,231, granted to the Western Union Telegraph Co. as assignee of Edison, May 3, 1892. The carbon telephone patent will be controlled by this company under its agreement with the Western Union Telegraph Co. It is necessary to add, however, that Edison's foreign patents for the same invention, although applied for subsequently to the application in this country, had expired previously to the grant of the American patent. Our counsel inform us that the law is unsettled, whether in such cases the American application should be defeated by the expiration of the foreign patent." . . .

The question involved was determined by the Supreme Court in the case of *Bate Refrigerator Company v. Ferdinand Sulzberger et al.*,

⁷ Ref. (30).

⁸ Ref. (31).

⁹ Annual Report, A. B. T. Co., March 31, 1896, pp. 13, 14; Ref. (32).

¹⁰ Ref. (32).

¹¹ Ref. (33).

which held in substance that the domestic patent, in such case was determined by the expiration of the foreign patent, notwithstanding that the domestic application was earlier than the application for the foreign patent. The result of the decision was to annul the Edison patent.

CHAPTER VI

THE BEGINNING OF THE OVERHEAD-WIRE PLANT

IN view of the fact that, at first, the only precedents for telephony to follow, in the stringing of wires, were those which had been created in applying the telegraphic art to commercial uses, some information that has been obtained about the first commercial telegraph line in the United States may be of interest. This line was constructed between Baltimore and Washington by Morse in 1844, under a grant of \$30,000 from Congress. Morse's mind from the first had been pre-possessed in favor of underground lines, and he ordered to be made, in New York, forty miles of five-wire cable, enclosed in lead, which was to be laid in a trench plowed in the ground. Seven miles of this cable were laid from Baltimore to the Relay House, but, on testing it, the leakage was found to be so great that it had to be abandoned. After the failure of this cable it was decided to place the wires upon poles.

On February 7, 1844, Morse inserted the following advertisement in the Washington newspapers:

"Sealed proposals will be received by the undersigned for furnishing seven hundred straight and sound chestnut posts with the bark on and of the following dimensions, to wit: Each post must not be less than eight inches in diameter at the butt and tapering to five or six inches at the top. Six hundred and eighty of said posts to be twenty-four feet in length and twenty of them thirty feet in length. All of the aforesaid posts are required to be delivered on or before the 10th day of March next, at the Baltimore and Ohio Railroad Depot in the City of Washington, and subject to the inspection and approval of the undersigned. Proposals must be submitted not later than February 20th, 1844."¹

These were doubtless the first American specifications for poles. It is interesting to note, in papers still on file in the Treasury Depart-

¹ Ref. (34).

ment, that these poles were delivered at a cost slightly less than one dollar each and that about ten per cent of the first delivery was rejected as not meeting the specifications. According to a letter from Professor Morse to the Secretary of the Treasury, dated June 3, 1844,² these poles were set about 300 feet apart. The crossarms were two feet long, one and one-half inches thick, and four inches high. They were placed at the very top of the pole, set into a mortise cut in the top of the pole, and afterward nailed into place. A short distance from each end of the crossarm, on the upper side, there was a rectangular slot, one inch wide and one and one-half inches deep, and in this slot were placed two small blocks of wood holding the wire between them. The faces of these blocks that were in contact with the wire were covered with felt or burlap. Across the top of the crossarm was nailed a roof block, which served the double purpose of holding the wire tightly in place and shedding the rain so that the water would not reach the insulating blocks. It is said that, shortly after the building of the line, the insulation began to fall rapidly, and men were sent out with long-handled brushes and pails of asphaltum with which they swabbed the felt insulators.

The wire used in the abandoned cable was No. 16 B. W. G. (65 mils) soft copper wire and was insulated with cotton saturated with shellac. When the cable proved defective, it was removed to the basement of the Patent Office, in Washington, where the lead was stripped off. The wire, still covered with its cotton insulation, was used in constructing the overhead line.³

Improvements in the methods of supporting overhead wires followed rapidly, as the telegraph plant developed and spread, but telegraph lines were essentially intercity lines, akin to telephone toll lines, whereas the early use of the telephone soon developed the fact that large numbers of telephone wires would be needed in exchange construction in cities and towns to connect the telephones with a central office. This required a type of construction differing from that employed for intercity lines, for, as has been said, these "came by the mile" whereas, telephone exchange plant "came by the acre."

The first wire line constructed for regular telephone use was opened in Boston on April 4, 1877. It connected the office of Mr. Charles Williams, Jr., 109 Court Street, Boston, with his residence in

² Ref. (34).

³ Ref. (34).

Somerville, Mass. The opening of this line was noted in several Boston newspapers, published April 5, 1877. The *Boston Daily Globe* said:

"Professor A. Graham Bell, the inventor of the telephone, had the pleasure of assisting yesterday at the opening of the first regular telephonic line in the world—a private line between the place of business of a gentleman in this city and his residence in Somerville. The instruments worked admirably, and the enterprising gentleman is very much pleased with his private telephonic wire between town and home. The practical value of Professor Bell's invention is being newly proved every day."⁴.

For a short time only, the early telephone lines were erected for the purpose of connecting pairs of telephones together for private-line communication. With these private lines each person having a telephone could talk to one other telephone and never to any others. It was a very simple arrangement but also very limited. One way of giving a general, intercommunicating service between all the telephones in a certain area would have been to provide each telephone with lines leading to every other telephone in the area. But it was seen that, if this were done, the number of lines would increase very rapidly as the number of telephones increased, and that the most practical way of providing the facilities for interconnection would be to bring the lines from all the telephones to a single point where facilities could be provided for connecting them together as desired. Although, at that time, each line consisted of but a single, grounded wire, the growth of the business was accompanied by a considerable concentration of wires along a number of routes approaching the central office. In some cases these wires were carried on crossarms on tall poles planted along the curb lines on the streets, and in other cases they were attached to racks placed on the roofs of buildings. Some of these racks were thirty-six feet high and carried two hundred or more wires. Some idea of the extent to which this house-top construction prevailed can be had from Figure 12, coupled with the fact that when, in 1880, the telephone plants of the Bell Telephone Company of New York and the Gold and Stock Telegraph Company of the same city were consolidated into the Metropolitan Telephone and Telegraph Company, an inventory showed that the latter received from the former

⁴ Ref. (2), p. 198.

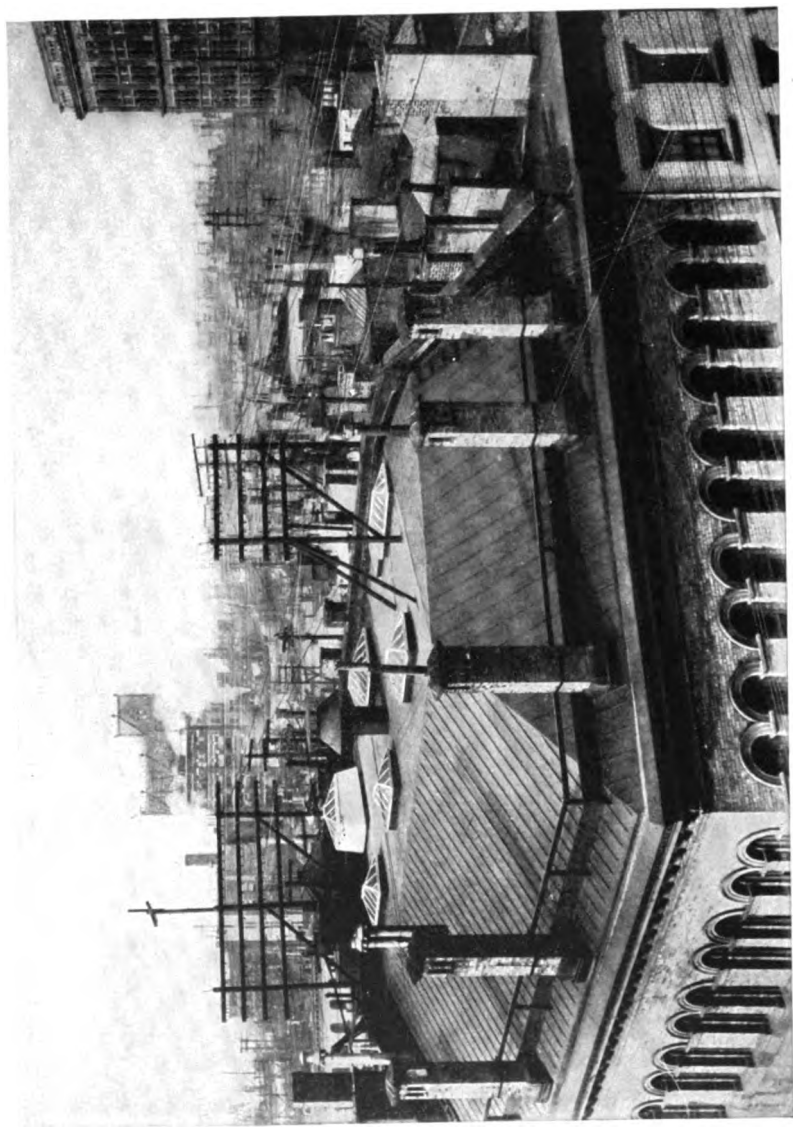


FIG. 12.—House-top construction in New York City about forty years ago. The building of the Corn Exchange Bank at 13 William Street is shown in the foreground.

companies, 1,892 miles of pole wire and 970 miles of house-top wire on 1,117 house-top frame fixtures.⁵

At the central office buildings it became necessary to terminate these overhead wires, sometimes to the number of several thousand. The method employed for doing this was to erect, on the roof of the central office building, a huge frame structure, or tower, to which the wires were attached. Figure 13 is a photograph of one of these structures erected on the roof of the central office building at 40 Pearl Street, Boston. It is said that at one time it had two thousand wires attached to it, and all of these were carried up to it over house-tops, there not being a pole within half a mile of the exchange. It is needless to say that these cumbersome structures with the mass of wires which they supported were highly vulnerable to sleet storms, which coated both the structure itself and the wires heavily with ice. Under such conditions it was not unusual for the wires to break or the structure to collapse. Sometimes weeks would elapse before the ruin could be cleared away, a new structure built, and telephone service restored. A report presented in 1881 to an assemblage of telephone men, dealing with the pressing question of finding some satisfactory method for placing the wires underground, stated, in part:

"The immense growth of wire mileage, increase in cost of maintenance, unreliability of the wire service, the unsightly appearance of wires, and last but not least the results and effects of the January sleet storm, command us to enter actively into the consideration of the subject. . . . We have seen a large and successful system with over 3,000 subscribers and upwards of 3,500 miles of wire completely wrecked in a single night; roofs torn off and walls damaged; poles broken off in a continuous line; persons and property damaged, and wires twisted into an inseparable mass that three months' incessant labor has not yet reconstructed." ⁶

The wires used in the beginning were of iron or steel. In some places they were galvanized with a zinc coating and in other places they were plain without any protective covering. Where iron wire was used, it was generally No. 12 (109 mils in diameter), and where steel wire was employed it was usually No. 14 (83 mils in diameter).

⁵ Ref. (35), p. 154.

⁶ Ref. (36), pp. 39, 40.

Even with the galvanized wire, troubles from corrosion were frequent and some experimenting was done with phosphor-bronze wire and with compound wires. One form of compound wire was made by wrapping a steel core with a copper ribbon, the whole being tinned afterward. An old-time telephone man, speaking in 1881, said: "This wire would soon become spoiled, for the reason that the copper ribbon would become separated . . . and galvanic action would take place, soon eating out the steel core."⁷ Another form of compound wire that behaved somewhat more satisfactorily was made by depositing copper on a steel core by an electrolytic method. The advantage of the high conductivity of copper as a material for line wire was appreciated, but the methods of manufacture that were then available did not enable a copper wire to be made of reasonable size that would have the necessary strength to permit of its use in spans stretching from one pole to another.

With the use of grounded lines, noises and overhearing were causes of annoyance. As General J. J. Carty has aptly said, speaking of those times: "A wire was strung from Boston to Lawrence, about 26 miles, on a telegraph line. Anybody listening on that telephone wire could hear all the telegraph messages. It was as though we had an old-fashioned drum corps and each drummer began drumming a separate tune."⁸

About 1883 a new iron wire was made which, it was claimed, would be free from inductive disturbances. Its cross-section was shaped like a four-leaf clover and the grooves ran around the wire in a spiral. The company that was making and promoting this wire interested themselves in its use on more than a dozen experimental lines. They had a theory that the voice current would follow the spiral and in some way produce a beneficial effect. An officer of the spiral wire company said it was not understood by electricians.⁹

The various compound wires of the time, and, in fact, iron and steel wires generally for intercity lines and largely for urban lines, were put out of the running by one of the most far-reaching contributions ever made to telephony—the development of hard-drawn copper wire.

During this early period of fumbling and groping in the dark,

⁷ Ref. (36).

⁸ Ref. (44); also *Bell Telephone Quarterly*, vol. i, no. 1, April, 1922, p. 27.

⁹ Ref. (38), p. 59.

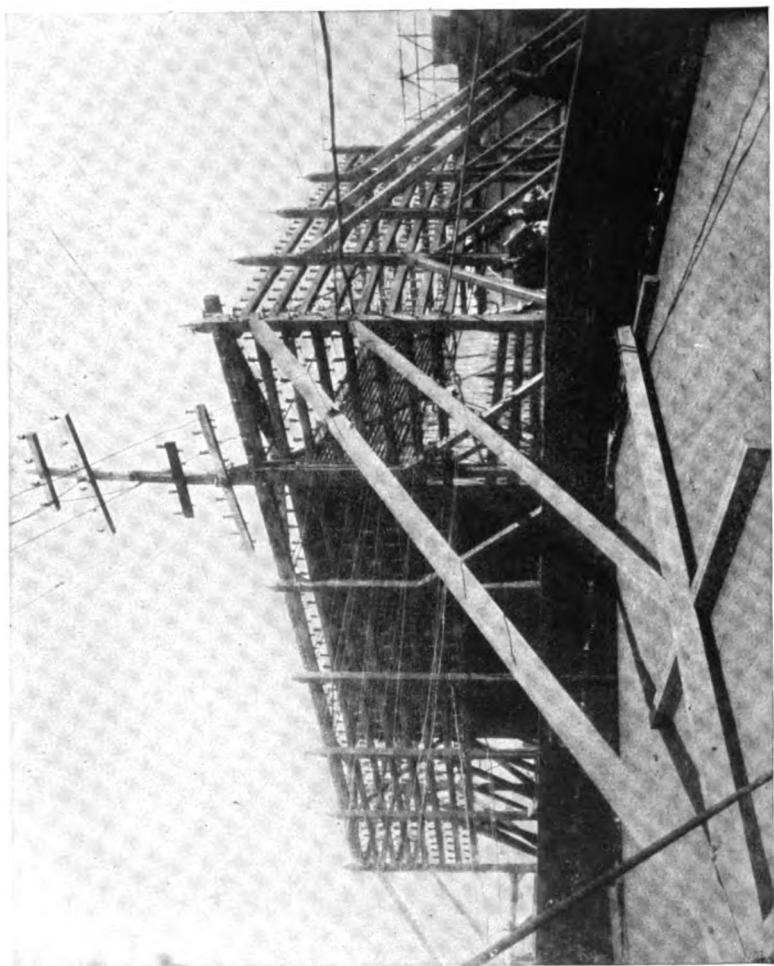


FIG. 13—Wire terminating structure on the roof of the telephone central office building at 40 Pearl Street, Boston, Massachusetts. Photograph dated June 1, 1883.



there was one man with clear vision who saw and understood that if copper wire could be made with suitable mechanical strength, it would be what was desired for telephone lines. His name was Thomas B. Doolittle.

Mr. Doolittle, from previous experience, was familiar with the physical properties of copper and the factory process of wire drawing. It occurred to him that, if a copper rod could be drawn cold through a series of dies, he could obtain a wire of much greater tensile strength than that of the soft, annealed wire which was the only kind of copper wire then manufactured commercially. In November, 1877, he made arrangements with the Ansonia Brass & Copper Company to supply them with telephone service between their mills and Ansonia, a distance of about half a mile. In connection therewith, he obtained permission from their superintendent to carry on his experiments in their shops, and with the aid of some of their skilled workmen, he succeeded in producing a quantity of hard-drawn copper wire, which was strung on poles between their buildings and connected for telephone service on December 4, 1877.

In September of the following year, Mr. Doolittle requested the same company to manufacture a quantity of hard-drawn copper wire for use in the Bridgeport telephone exchange. The first lot made proved to be too brittle and inflexible for his purposes, and another lot was ordered on October 1, 1878. This turned out satisfactorily and it was used as telephone line wire at Bridgeport and remained in service until 1891, when an underground cable system was introduced.

In 1881, at the direction of Mr. Vail, then General Manager of The American Bell Telephone Company, a section of the original wire at Ansonia, and also samples prepared by two other manufacturers, were tested under the supervision of Mr. T. A. Watson. The results of these tests were such as to encourage Mr. Vail to experiment further; and in 1883 the engineers having reported that hard-drawn copper wire would sustain the strains to which it might be exposed almost as well as iron wire, it was decided, upon Mr. Vail's recommendation, to build an experimental long-distance line between Boston and New York.

On May 25, 1883, an order for five hundred miles of hard-drawn copper wire was placed with the manufacturers, and the actual construction of the line, a large part of which was built by the Southern New England Telephone Company, was begun in November, 1883.

Mr. Doolittle was directed by Mr. Vail to supervise the erection of the line, and on March 27, 1884, the first conversation over the line took place.

In October, 1884, after an elaborate series of tests had been made on samples of hard-drawn copper wire obtained from a number of manufacturers, Mr. Vail concluded that, if a line could be built upon which wires of different sizes would be placed, experiments might be carried on which would give valuable information as to the proper size or sizes to use and as to the electrical and mechanical characteristics that the wire should possess for long-distance service.

With this end in view, a line was built between New York and Philadelphia, in 1885, having a capacity of 70 wires, and 24 hard-drawn copper wires of various sizes were strung upon it for purposes of experiment. Those which were mechanically weak were eliminated, and much important knowledge was obtained in a carefully conducted series of experiments carried on over this line. The demand for hard-drawn copper wire for telephone purposes had by this time caused several manufacturers to undertake its production, and it soon came into general use for the transmission of electricity. With the subsequent development of electric lighting, traction, and power transmission, its use was rapidly extended throughout the electrical industries. Hard-drawn copper wire and its process of manufacture were never patented.¹⁰

The Beginning of the Metallic Circuit in Telephony

A highly important advance in the telephone art was the realization of the advantages of the metallic, or two-wire circuit. The circumstances under which the benefits of the metallic telephone circuit first became apparent were as follows:

“The combination of a telephone wire, or a telegraph wire used telephonically, with an additional metallic wire running parallel with the said telephone wire, and in close proximity thereto, but insulated therefrom, the wires being connected at each end to complete the metallic circuit.”

These words were used to describe the matter of an interference in the United States Patent Office between the application of Alexander G. Bell, filed December 20, 1878, and the application of David

¹⁰ Ref. (74).

Brooks, filed March 4, 1878.¹¹ Both sides started with the admission that a metallic circuit was not new. Bell himself in his specification set out his disclaimer in these words: "I am aware that two wires have been before used in working telegraphic instruments in place of sending the return current by the earth, and I do not lay claim to the use of two wires generally, or otherwise than when they are used in the manner I have described."¹² In a British Patent, No. 2,089, September 15, 1855, Werner Siemens had described, for telegraphy, "A set of two insulated wires placed in close proximity to each other, and imbedded in the middle of one mass of gutta-percha or other insulating material as one electric circuit, in which the battery and receiving instrument are inserted, without using the earth as part of the circuit."

The particular arrangement of the two wires composing the metallic circuit which Bell claimed to have discovered was described by him in his deposition taken before the Honorable Commissioner of Patents as follows:

"The method by which I sought to accomplish this result, on the 26th of November, 1876, was to employ a metallic circuit, the direct and return wires of which should be parallel to the disturbing wires, and to one another, and should be placed as near to one another as practicable. . . . The improvements in the arrangement that I devised in England were:

1. To place the direct and return wires close together, and to place around them a common cover or envelope of such thickness that the telephone wires should always be so very much nearer to one another than they were to any other adjoining wires that they would be for all practical purposes equally distant from such wires; and
2. To twist the direct and return wires around one another, so that they should be absolutely equidistant from the disturbing wires."¹³

The interference was declared January 29, 1879, and an appeal by Brooks was decided by two Examiners-in-Chief, who awarded priority to Bell. A patent issued to Bell (U. S. Patent No. 244,426,

¹¹ Ref. (46).

¹² U. S. Patent No. 244,426.

¹³ Ref. (45), pp. 17, 18, 19.

July 19, 1881), in the text of which was said: "With twisted wires the relative distances of the wires is of little or no consequence, so far as obviating inductive disturbance is concerned, since by the twist the wires of each pair are brought alternately to the same position relative to the other wires."

In 1880, the Inter-State Telephone Company undertook to build a telephone line from Boston to New York. They built one section of this proposed line, in 1880, from Boston to Providence. It had two crossarms, each bearing two No. 9 galvanized iron wires. The first public demonstration of telephoning over this line occurred on the evening of January 10, 1881, in the presence of groups of prominent business men, telephone officials, and others. The opening of the line for commercial business was on January 12, two days after the exhibition. No business was accepted to points beyond the limits of the Providence exchange and the Boston exchange of the Telephone Despatch Company.

J. J. Carty was at that time engaged in electrical work for the Telephone Company in Boston. He describes the events which made this line a landmark in telephone history, as follows:

"On two of these wires an anti-induction appliance was used, consisting of a galvanized iron or zinc sheath around each pin, the sheaths being connected together and grounded. As might be expected, this was not a success and was removed. Soon after the line was built, violent disturbances from a high-speed chemical telegraph were experienced. This telegraph was known as the 'American Rapid.' The disturbances were so great that the line was a practical failure. . . . One day, upon my own initiative, I connected wires 1 and 2 together at Boston and looped my telephone and transmitter into the circuit. I gave directions to the girl at the Providence end, showing her how to connect the two wires at that end. This she did and I shall never forget the remarkable change which it made. The whirr of the American Rapid was practically eliminated, and the line was so quiet that all of the noises of the Providence operating room were loudly heard by me at Boston. The operator asked me what caused the change and I told her I put the line on metallic circuit. . . . She said, 'I wish I had one of those things down here.'"¹⁴

¹⁴ Ref. (74).

General Carty was, therefore, the one who first introduced the metallic circuit into commercial use on telephone lines. The advantages of this forward step were set forth in a circular, advertising the service, in the following words:

BOSTON AND PROVIDENCE
EX-TERRITORIAL TELEPHONE EXCHANGE ¹⁵

The Inter-State Telephone Company respectfully invite your attention to the advantages of their projected ex-territorial exchange between Boston and Providence, which, it is hoped, will commend itself to you in such a manner as to secure your subscription.

A limited number of parties in Providence and Boston, who have frequent occasion to communicate with each other, will be formed into an exchange, a subscription to which entitles any subscriber in Providence to talk with any subscriber in Boston, or *vice versa*. A call bell, telephone and transmitter, all of the latest patterns, will be placed on the premises of each subscriber, and connected by a *metallic circuit* with central operating tables in Boston and Providence, which tables will be connected with each other, also on a *metallic circuit*.

Thus, any subscriber in one city can be quickly connected and talking with his correspondent in the other city *on a complete metallic circuit, ensuring a perfectly quiet line*, free from all sorts of induction or earth currents, with no possibility of being disturbed by the conversation of others, or of having your own conversation overheard by them. No condition of the atmosphere and no trouble short of an absolute breakage of the line can interfere with the perfect working of this system.

Each subscriber has, practically, a *private line on a metallic circuit*; the only perfect system of telephony yet devised. For obvious reasons, we shall limit subscriptions to this ex-territorial exchange to a very small number, and your attention is invited to the advisability of making an early application for its benefits.

For further information and terms of subscription, apply to

C. H. BARNEY, *General Manager*,
Room 27, (3rd Floor), Butler Exchange,
Providence, R. I.

November, 1881.

Appreciating that the introduction of the metallic circuit system in exchange plants would necessitate reconstructing practically the entire plant and increasing the already burdensome mass of overhead wires, telephone engineers, at this time, endeavored to find other and less costly methods for reducing the troublesome electrical disturbances. One of the methods of which some use was made was advocated by

¹⁵ Ref. (47).

Mr. C. E. McCluer. It consisted in using a common return wire, of low resistance, disconnected entirely from the earth, as a "general ground wire." This return conductor was carried on the same poles with the main wire routes and was, therefore, parallel to the line wires with which it was used. While the common return wire reduced the disturbances due to ground potentials, it fell short of successfully eliminating the troubles from induced currents.

The last decade of the past century was a crucial period in telephony. In an important paper entitled "The New Era in Telephony," by Messrs. Hibbard, Carty, and Pickernell, read by Mr. Carty before the National Telephone Exchange Association, at Minneapolis, in 1889, it was made clear that the metallic circuit was the essential basis upon which rested the furnishing of improved telephone service. In this paper was stated:

"Grounded circuit methods, as they have been generally practiced in telephony, are not satisfactory when applied to metallic circuits. The great underlying principle has been found to be that a perfect balance of the two sides of the circuit throughout its entire length is necessary to the best results, and to maintain and preserve this balance requires the closest attention to every detail. In other words, the new service requires: first, proper engineering, second, a force educated and trained to carry out the plans provided."

The provision of metallic circuits required the doubling of the outside wire plant, which was, in itself, a physical and financial problem of the first magnitude. Another difficulty presented itself in the case of the switchboards. Where new switchboards were to be installed, they were constructed on the metallic circuit principle, but there remained, for some time, large switchboards that were wired only for grounded lines.

For use during the transition period from grounded to metallic lines, special circuits and apparatus had to be devised, and all arrangements had to be such that, as the grounded lines passed out of existence, a proper metallic circuit plant, including switchboards, cables, and overhead wires should remain. It is impossible at the present time to realize, adequately, the complexity and difficulty of the problems that had to be solved, in providing switchboard arrangements that would permit mixed circuits (that is, both metallic and

grounded) to be handled and also allow the gradual conversion from grounded to metallic lines. Practically the entire plant had to be made over without service being interrupted. This stupendous task was performed largely between 1890 and 1900. That epoch was a turning point in the history of telephony.

Pole Lines

When the so-called "long-distance" lines began to be rapidly extended, a new era was reached in the standard methods of pole-line construction. These lines were notable for their symmetry and general shipshape appearance. The first standard specifications* for their construction, of which a record has been found, called for forty-foot poles of live cedar or chestnut, not less than seven inches in diameter at the top; cedar poles to be at least 17 inches and chestnut poles 12 inches at the butt. Cedar poles had the advantage of being straight and comely in appearance and they were comparatively light in weight, thus facilitating transportation and erection. Chestnut had the advantage of being a considerably stronger timber, thus permitting the use of a smaller pole, but the weight of chestnut was nearly twice that of cedar poles of the same size. As cedar poles were readily available at that time from Michigan and Canada, the specifications for the poles for the long-distance lines, adopted in 1892 and 1893, named cedar poles as the standard. Beginning late in 1893, the specifications again provided for the use of chestnut poles.

Insulators

In the early days of telephony, the wires carried on poles and fixtures were attached to the crossarms either by means of glass insulators supported on wooden pins projecting up from the crossarm, or by means of porcelain knobs attached by screws to the under side of the crossarm. Speaking of the latter method of support, in 1887, the late Thomas D. Lockwood said:

"But the porcelain knob lunacy is not so easily accounted for. I suppose, first, the unsophisticated exchange man assumed that the only use of an insulator was that of an attachment; that he later undertook to study electricity and ascertained that porcelain was a non-conductor, and that thereupon he jumped to the conclusion that all porcelain articles must be well adapted for line

* A. T. & T. Co. Specifications No. 24, February 25, 1891.

insulators. How was he to know that the efficiency of an insulator depends as much on its form as on its material?" ¹⁶

Some time elapsed before it was generally appreciated that even though insulators are made of glass and mounted on wooden pins, there is a certain amount of conduction of the telephone current over the surface of the glass when it is wet, and this leakage is intensified by the presence of the dust and dirt with which the insulators are prone to become coated. In order to render the insulators effective in wet weather, a portion of the glass is kept dry by molding the lower part of the insulator in the shape of a bell or skirt. The contour of this skirt follows in a general way the form of the supporting pin, but the inner surface of the skirt is separated from the pin by an air space which is made so narrow that raindrops, splashing on the top of the crossarm, will not enter it appreciably. In the subsequent design of these insulators much attention has been given to obtaining the most effective relation between the length of the leakage path and the area of the surface in order to obtain the best insulating properties.

Transpositions

At a meeting of telephone officials, in 1886, the General Manager of the American Company said:

"We found that between metallic circuits with wire connected straight through, there was a very considerable amount of cross-talk, not quite as much perhaps as there would have been on grounded circuits, but not materially less. We have entirely removed that by securing a balance between the circuits." ¹⁷

His reference was to the working out of an elementary scheme of wire transpositions, by John A. Barrett (U. S. Patent No. 392,775, November 13, 1888), who was delegated to solve the problem through experiments conducted in 1885 on the New York-Philadelphia line. He started by laying out a lot of twisted-pair wires on the floor of a building. Speaking on May 15, 1890, before the New York Electrical Society, J. J. Carty said, "The true theory of transpositions has never been published, and I do not know half a dozen men who could design a transposition system for a twenty-wire line from New York to Buffalo." ¹⁸ The basic theory underlying the principle of trans-

¹⁶ Ref. (42), p. 55.

¹⁷ Ref. (41), p. 127.

¹⁸ Ref.: *Electrical World*, May 24, 1890, p. 344.

posing wires was elucidated by Mr. Carty in a classical paper* presented before the American Institute of Electrical Engineers at New York City, in March, 1891, in which he pointed out the predominating importance of electrostatic induction in the practical working of telephone lines to which he had called attention, for the first time, in a paper† before the New York Electric Club in 1889.

The original system of transpositions was a simple and limited one. As the number of wires on a line increased, as the electrical transmission of power developed, and as phantom circuits came into use, many new transposition systems had to be painstakingly worked out. Much of the more recent work of transposition design has rested on an elaborate series of measurements of direct capacities made for the American Company by Mr. E. H. Colpitts in 1904.¹⁹ With each important change in the art of transmitting electrical power, new tasks have been set for the telephone engineers in devising improved systems for transposing not only the telephone wires, but, in some cases, the power wires themselves.

* "Inductive Disturbances in Telephone Circuits," J. J. Carty. A. I. E. E. Meeting of March 17, 1891.

† "A New View of Telephone Induction," paper presented by J. J. Carty, New York Electric Club, November 21, 1889.

¹⁹ Ref. (74).

CHAPTER VII

THE BEGINNING OF THE TELEPHONE CABLE

THE earliest use of cables for telephonic purposes occurred where it became necessary to carry the wires across navigable rivers. At the very beginning, as was the case with the overhead-wire plant, the infant art of telephony turned to the older telegraphic art, to avail itself of what the latter had to offer. As gutta-percha and various compounds of rubber had been used extensively for a long time as the insulating materials in telegraphic cables, it was natural that the first cables for telephonic use should employ these materials.

The predecessor of the Metropolitan Telephone and Telegraph Company, in New York City, had cables on the Brooklyn Bridge structure as early as 1879, years before the bridge was opened for roadway traffic. The electrician of the Metropolitan Company, speaking in September, 1880, said:

"We have over the East River Bridge at the present time, four cables, 3,800 feet long, each cable with seven conductors. These cables have taken the place of cables that were previously there with the ordinary Kerite insulation and gutta-percha. In using the cables and talking on one wire, you could hear whatever was said on another wire, and by wrapping each conductor with lead and grounding at intervals, all of the escape and all induction were completely eliminated. These cables have been in use, two of them for six months, and one for nine months, and are now working perfectly."¹

The metallic (two-wire) circuit had not yet been employed. For several years to come, the problem of avoiding the overhearing of conversation from one cable wire to another was destined to occupy the minds of the workers in the telephone field. From the nature of the insulating materials employed, the cables were high in electrostatic capacity. Not only did this render them inefficient as conductors of

¹ Ref. (35), pp. 51, 52.

currents at voice frequency, but also it contributed so greatly to the trouble from overhearing that much activity was expended in devising "induction killers," as they came to be called. It was unfortunate and disheartening that those devices which were the most successful in "killing" induction, killed the regular transmission as well! The best results at that period were obtained by placing each telephone wire in the cable within some sort of metallic sheath.

At about the same time, in 1880, a cable similar to those placed on the Brooklyn Bridge was laid between New York and New Jersey under the North River. It was described as "an ordinary Bishop gutta-percha cable with each conductor covered with lead." There were seven conductors in this cable, and it is stated to have cost \$1.05 per foot.² The Bishop Gutta-Percha Works at that time advertised themselves to be the "original and only" manufacturers in the United States of gutta-percha insulated cables. The American Bell Telephone Company, for itself and its licensees, acquired a non-exclusive license from the Bishop Gutta-Percha Company, so that when the use of such cable was desirable, better arrangements could be made with the holders of the patent than would otherwise have been the case.³

The gutta-percha cables by no means had the field to themselves. What was known as the Brooks System was used to such an extent as to warrant more than passing mention.

In the Brooks System, each conducting wire was covered with cotton, and wrapped spirally with a very light copper wire, also insulated with cotton, to serve as the induction shield. A group of the wires, thus wrapped, was made into a rope, or cable core, which was covered with cotton and drawn into an iron gas pipe.

The gas pipe was then filled with paraffin oil or a high-test illuminating oil. A standpipe and reservoir, containing several gallons of the oil, was connected to the piping system for the purpose of maintaining the oil under pressure and, in the event of a leak, preventing water from entering the pipe.

Speaking of the Brooks System, in 1880, Mr. Enos M. Barton, who later became president of the Western Electric Company, said that it had been tested experimentally between two and three years, and that "the longest section which is in operation is one across the Delaware River from Philadelphia to Camden. That has been pulled

² Ref. (35), pp. 47, 48.

³ Ref. (35), p. 52.

out and breaks have occurred in the pipe. There have been difficulties in the reservoir at one time, which ought to have contained oil but was found to contain water, which necessitated pulling out the whole length of cable, but that work has been done over again and the cable is still there.”⁴ Prior to September, 1880, there were six Brooks cables in service in Milwaukee, Wisconsin, each cable being about 500 feet long and containing 50 conductors. They were placed beneath the navigable rivers which intersect that city.⁵ As late as 1885, the Brooks System was in use at the Spring Street Exchange in New York City. That installation, with others contemporaneously employed, will be described later.

In 1879 the use of cables for telephonic purposes in Chicago began with the installation of a 50-wire Brooks cable, 925 feet in length, in the Washington Street tunnel under the bed of the Chicago River. It was followed, in 1880, by a 75-wire cable of similar construction, 450 feet long, placed in the La Salle Street tunnel and, in the spring of 1881, by another “exactly like this last,” in the same tunnel.⁶ Another type of cable, of which some use was made about this time, was that of David Brooks, Jr., a son of the inventor of the Brooks System described above. The wires were of copper, about No. 18 gauge, covered with cotton and twisted together in pairs of which one wire was grounded. A lead sheath was applied, after which a mixture of resin and paraffin was forced in, in a liquid state, and allowed to cool. A cable of this type, about 600 feet in length, was installed at Philadelphia in May, 1880, between two central offices. There were 84 wires in a one-inch lead pipe. Forty-two of the wires were working and 42 were grounded to reduce induction trouble. The cable was hung from a wire stretched between fixtures placed between the offices.⁷ In New York City, the Metropolitan Company had almost exactly the same kind of cable, differing only in the number of wires, there being 40 working wires—that is, 80 wires in all. This New York cable was 1,665 feet long. Six hundred and fifty feet of it was suspended over openings and streets, the longest span being 160 feet. Where the cable was suspended, it was bound with

⁴ Ref. (35), p. 46.

⁵ Ref. (35), p. 52.

⁶ Ref. (38), pp. 67, 68.

⁷ Ref. (35), pp. 48, 49.

copper wires to a wire rope; where it passed over house-tops, it was laid on the roofs.⁸

In Chicago, in the summer of 1880, a David Brooks, Jr. cable of somewhat different construction, 925 feet long, was placed in the Washington Street tunnel. This cable consisted of 50 conductors of about No. 21 copper wire, insulated with cotton. Around each conductor, over the cotton insulation, was spiraled a flat strip of thin copper to form an induction shield by grounding it at both ends.⁹

The cable core was drawn into a light lead pipe before leaving the factory, and the pipe was then filled with a "mixture of hot resin and beeswax, or some similar compound, so as to protect the cotton insulation from moisture."⁹

Some unique ideas in cable construction, suggested at about this time, came into more or less limited use. There was the Delaney Button cable.¹⁰ "To illustrate its construction, imagine four No. 20 copper wires run through a long string of ordinary shirt buttons, the buttons arranged close together; forming a flexible cable that can be wound on a reel and drawn through whatever sized pipe or conduit desired."

And in 1881 there was in use in Chicago about 500 feet of a cable consisting of about 20 bare wires, each one drawn into a small glass tube. A group of these tubes, each containing a wire, was then drawn into a lead pipe and a solution of some kind of grease and resin forced in under pressure. When the lead pipe was bent the glass tubes of course were broken, but the desired separation of the wires was said to have been maintained by the injected material holding the glass in place.¹¹

The London *Electrician*, for August 20, 1881, carried the following news item, commenting somewhat cynically upon the prevailing American methods:

THE LATEST THING IN OVERHEAD WIRES

We hear that the Telephone Despatch Company of Boston, U. S. A., has tried an experiment in aerial lines as follows: A pipe of galvanized iron has been suspended from a strong strand, consisting of three large wires, for a long stretch of upwards of 500 feet, and in it were placed

⁸ Ref. (36), p. 30.

⁹ Ref. (38), p. 68.

¹⁰ Ref. (36), p. 20.

¹¹ Ref. (36), pp. 52, 53.

about 150 covered copper wires. The effect will no doubt be very striking some day.

As no evidence has been found of any one being struck, it seems probable that this aerial cable, if it ever existed, was replaced by an improved type, the result of American enterprise and progress, before the predicted accident could occur; but no American record of the existence of a structure of this kind has been discovered.

Overlapping, in point of time, the use of gutta-percha and Brooks cables of both types, came the introduction of cables having the conducting wires insulated with rubber compounds and with cotton impregnated with paraffin. By 1882, the cables used were chiefly those of three manufacturers: Eugene F. Phillips, of Providence, R. I.; A. G. Day, of New York; and the Western Electric Company, of Chicago.

The Phillips cable had each individual conductor covered with rubber compound, in some cases with an envelope of tin foil applied over the rubber. An outer insulating cover was placed over the group of wires forming the cable, and an external protecting coat of waterproof canvas woven outside of all.

The Day cable consisted of a number of copper conductors each insulated with a rubber compound, the trade name of which was "Kerite." Over this compound, tin foil was sometimes applied as an induction sheathing. This had several leading-out wires for connection to ground. A strong covering of Kerite tape was placed on the outside.¹²

In the Western Electric (Patterson*) cable, the copper wires, insulated with cotton, were placed in a lead pipe and completely embedded in paraffin which was forced into the pipe in a liquid state, impregnated with carbonic oxide gas to secure a lower specific inductive capacity.¹²

The Western Electric cables which were intended for suspension were provided, outside the sheath, with a pair of stout iron wires which were twisted in a long spiral around the sheath and were bound to it by a smaller wire. The two large wires were at opposite ends of a diameter of the sheath and, at intervals of about three inches along the length of the cable, the sheath, the large suspending wires,

¹² Ref. (37), pp. 91, 92.

* The reference is to William R. Patterson, for many years cable expert of the Western Electric Company.

and the small binding wire were all soldered together.¹³ This was abandoned because the wires cut into the cable sheath.

In 1881 or 1882 there was some use made of what at that time was described as "a very original, practical, and effectual" method of cable suspension.¹ After the cable had been temporarily sustained below the suspending wire, a species of double reel, on which was wound tarred rope-cord, string, or spun yarn, was placed at one end of both cable and suspension wire and the outside end of the cord was fastened permanently at some fixed point. The reel was then drawn slowly and steadily from one end to the other of the cable, it being so contrived that, by its motion, the tarred cord, on leaving the reel, enveloped both suspension wire and cable in long spirals which lashed them together.¹⁴

In September, 1882, a 100-conductor Patterson lead-sheathed cable was placed in the Washington Street tunnel in Chicago. In describing it to an assemblage of telephone men, a representative of the telephone company in Chicago gave the following account of the wire conditions existing at that time:

"The system of house-top wires had grown into a forest of tall frames, cumbrous to handle and obnoxious to property owners. In the spring of 1882, it was decided to commence a gradual but sweeping change in this city by substituting aerial cables wherever the bodies of wires exceeded forty in number. It is not improbable that, at some time, city exchanges will be operated generally upon the metallic circuit system; and in buying cables which were intended to last for some years, it seemed advisable to have them made of pairs of conductors twisted together, so that each pair could be used as a metallic circuit if desired, in the future. We purchased some Patterson lead cables, made by the Western Electric Company, with this end in view. They consisted of fifty pairs of conductors of No. 26 copper wire. One wire in each pair is insulated with white cotton and one with red. The two are twisted together, and the fifty pairs are then twisted into a cable and boiled in paraffin; after this the cable is drawn into a lead pipe slightly larger than itself, and melted paraffin, charged with carbonic acid gas under a high pressure,

¹³ Ref. (37), p. 93.

¹⁴ Ref. (37), p. 94.

is forced into the pipe and allowed to cool, forming a solid cake of paraffin between the core and the pipe."¹⁵

It was not until 1887 that cables were universally made on a metallic circuit basis.

Sometime previous to April, 1882, the Boston Telephone Despatch Company placed an aerial cable 2,364 feet in length, extending from the central office at 40 Pearl Street to the United States Hotel. This cable contained 51 conductors of No. 20 copper. Each wire, after being double wound with cotton, and paraffined, was covered with rubber. Over the rubber of each conductor was then lapped a coating of tin foil "for the purpose of acting as a conducting surface for induced currents."¹⁶

A paragraph in the *Electrical World*, November 10, 1883, describes the progress being made in cable work in Cleveland as follows:

"The telephone wires in Cleveland, Ohio, are rapidly being put into cables, and they are working well over short distances. The company is using about 4,000 feet of cable now; about 2,000 feet of that is out of the Central Exchange to the Cedar Avenue Exchange. The largest piece is only about 1,000 feet long. The cable consists of a three-quarter inch lead pipe, in which is a cable consisting of fifty copper wires wrapped in two coats of cotton or jute, and surrounding a core of copper wire, perhaps a quarter of an inch in diameter. When this cable is introduced in the tube, melted paraffin is forced in, filling all the interstices of the insulation. This leaden tube is suspended by hangers, a foot apart, from an iron wire, No. 1 gauge* in size. Each of the small wires connects an individual telephone with the exchange, while the central large copper wire is grounded at both ends, and serves to carry off the induced currents."

As the development of telephonic cables subsequent to this time was closely interwoven with their use in underground ducts, it is now desirable to pass on to a review of the early work involved in putting the wires underground.

¹⁵ Ref. (38), pp. 68, 69.

¹⁶ The New York *Review of the Telegraph and Telephone*, April 15, 1882.

* Diameter 300 mils. At that time all iron and steel wire was rated in Birmingham Wire Gauge (B. W. G.).

CHAPTER VIII

HOW THE TELEPHONE WIRES WERE FIRST PUT UNDERGROUND

IN 1881 three Patterson cables, having 50 conductors each of No. 26 copper, were laid underground in Pittsburgh in a wooden box covered with pitch or asphalt. This installation was increased by eight cables the following year.¹ The placing of these wires underground indicated a growing appreciation of the fact that the huge structures on the house-tops and the towering poles on the main streets of the larger cities would not suffice much longer to carry the constantly increasing burden of overhead wires.

In the 1881 annual report of The American Bell Telephone Company may be found these words:

“A large amount of work has been done in the electrical and experimental department, both in examining new inventions and testing telephones and apparatus, and in studying the question of overhead and underground cables, and the improvement of telephones and lines, for both short and long distance service.”

The reference to long-distance service is clarified in the same report by the statement that “Boston, for example, is now in communication with seventy-five cities and towns, including Providence, Worcester, Springfield, Lawrence, Lowell, and other important places.”

The wires had to be buried, but the question was: how should it be done? The little band of electrical experts in the Telephone Company's laboratory at Boston were learning that wires in cables, insulated with gutta-percha, rubber, or paraffined cotton, although suitable for telegraphing, caused the telephone to work very badly, so that the voices of one's friends were frequently almost unrecognizable, the sounds being muffled and hollow, as though the speaker were talking through a barrel or as if they came up out of the earth. Unexpected troubles were met at every turn. Speaking of the difficulties of that period, Mr. Watson said, “My recollection of all this work

¹ Ref. (39), pp. 110, 111.

is chiefly characterized by a feeling of hopelessness I then had. I felt as if I were gazing into an abyss that must be bridged by lives of work and experiment before we could get to the other side."

But the problem of putting the wires in cables had to be solved or the business would have been stunted in its infancy. To reinforce its own experts, the company called to its aid professors of physics and of electrical theory from colleges and technical schools. Experiments and tests, carried on with painstaking care, began to point the way to improvements. A year later, in 1882, the annual report of the Telephone Company had more to say on the subject of cables:

"Our experiments in underground cables, while not as successful as we had hoped, have given sufficient promise of satisfactory results to warrant us in undertaking a considerable expense to test the different methods. With this object, we have asked permission to put down cables in Boston, and, as soon as the needed consent is obtained, we propose to make careful and thorough practical tests of the best systems offered. There is no strictly underground telephone system in any part of the world, the Paris wires being placed in huge sewers, practically large galleries, entirely altering the ordinary underground electrical conditions. Foreign companies are apparently waiting to see what is done in America; we have, therefore, nothing to guide us but our own experiments."

More than a hundred different schemes and arrangements had been proposed for putting the wires underground, and preliminary experiments were needed to throw light on a number of doubtful points. There were wide differences of opinion as to what the effect would be upon telephonic transmission of laying cables in the earth. In order to obtain definite information on these moot points, the American Company decided to lay five miles of cable underground between railroad tracks in Massachusetts for no other purpose than to enable tests and experiments to be made.

This was an event of importance, and one of the leading technical journals* of the day printed an account of it:

"Four miles of the cable was ready for laying by Sunday, April 16th, and upon that day, at half-past six in the morning,

* The New York *Review of the Telegraph and Telephone*.

Road Master E. M. Merrill, E. F. Phillips and W. H. Sawyer, the manufacturers of the cable, and H. B. Lytle, of the Telephone Dispatch Company, were on the ground with a gang of twenty laborers, and a locomotive to which was attached a box car open at the rear end and containing the tools to be used.

"The location chosen was the Boston and Providence Railroad between the stations of Attleboro and West Mansfield, and only on Sundays is the road sufficiently free from passing trains to admit of such an extensive operation as the laying of four miles of cable, under the surface of the ground between the tracks.

"It was decided to excavate a furrow or trench for the reception of the cable, and after considering how that might be dug most expeditiously, some one hit upon the happy thought of employing a plow; some men were accordingly sent out to procure such an implement of a farmer; but the first one consulted would not allow his plow to be used on Sunday at any price, and it was some time before one was obtained. Then a heavy beam was lashed to the rear of the car, the plow was chained to that, a man seized the plow handles, and the train started up, dragging the rusty shire (plowshare) through the closely packed gravel faster than any team which ever was driven afield.* And soon a single furrow five miles in length was opened ready for the reception of the pipe.

"Inasmuch as the cable consisted of numerous sections, each 530 feet in length, conveniences were required for connecting together the conducting wires; for this purpose, boxes were prepared into which the opposite ends of each two adjoining sections were run, and when the wires were properly connected, the boxes were made water tight and closed.

"When all the cable thus far received had been properly laid into the trench, an impromptu appliance was contrived with which to cover it up by steam; a stout plank was thrown out from the car at such an angle that when the train moved forward it would draw the gravel back into the furrow like a scraper, so that the cable was buried in a very short space of time.

"The remaining mile was laid on the subsequent Sunday with

* There is a tradition that the original plan was to turn the furrow with a plow drawn by oxen, but no farmer could be found who was willing to transgress the inhibition of the Decalogue as to the labor of oxen on Sunday.

equal success, and the entire job reflects great credit on Mr. Lytle, who has had charge of the mechanical details of laying.

"The cable itself, weighing nearly 30 tons, filled three freight cars and was constructed as follows:

"Twenty-one conducting wires, ten of which were, besides being insulated perfectly with rubber, covered with tin foil, which being in permanent contact with the earth through the intermediation of the enveloping pipe, is intended to conduct away any induced currents.

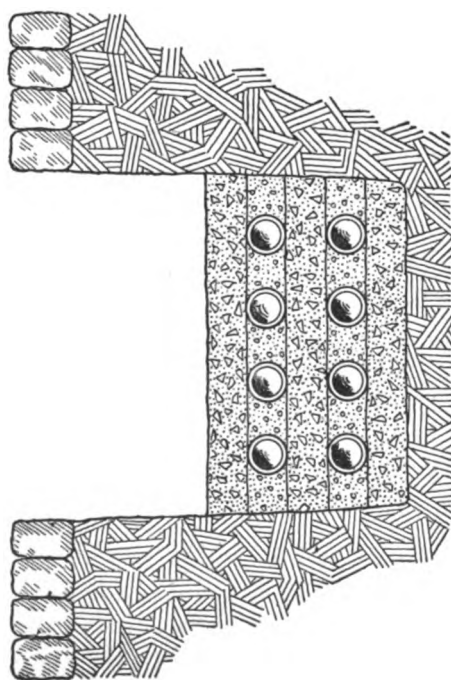
"Ten others were simply rubber-covered, and twisted together in pairs, while the twenty-first was an ordinary paraffin office wire, No. 13 gauge. The whole of the conductors are enclosed in a leaden pipe, and makes a cable three-fourths of an inch in diameter.

"The experiments with this cable will be performed by the electricians of The American Bell Telephone Company, and it is hoped will set at rest many vexed questions."

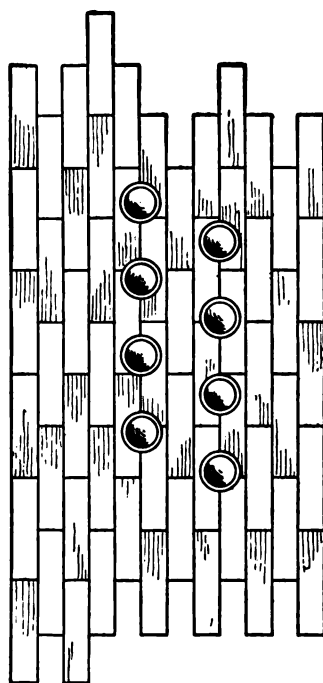
Far from encouraging were the results of the tests on this experimental cable, but it was decided to go on with the Boston installation and to construct, beneath the surface of the street, a system of ducts so that a cable which might "go bad" could be withdrawn and another pulled in to take its place. The annual report of the American Company of March 28, 1883, stated:

"In the work of putting wires under ground the progress has not been as satisfactory as could have been wished. Underground cables have been laid in iron pipes in Boston in two directions from the main office,—one line being 1,200 feet and the other 1,485 feet in length.

"Conversation is successful within short limits over these lines, but where they are used in connection with long lines—for instance those reaching to the suburbs—the voice becomes indistinct. Unless this difficulty can be removed, the connection with points outside of Boston would be almost if not quite useless to those whose wires were underground. With our present facilities for experiments we can readily test the value of such improvements as may appear, and we hope to get more definite results before long in this direction."



CROSS-SECTION IN STREET



ARRANGEMENT OF DUCTS ENTERING MANHOLE
 UNDERGROUND CONDUIT SYSTEM, CONSTRUCTED IN BOSTON, MASSACHUSETTS,
 IN 1882

The general planning of the work for this, the first telephone "drawing-in" conduit installation, was placed in the hands of Mr. Joseph P. Davis, an eminent civil engineer of extensive experience in the construction of water works, and he appointed Mr. W. H. Sears to act as engineer in charge of field operations. Records are available which give a clear and accurate picture of the construction employed.² Great care was taken at every step to ensure the permanence of the

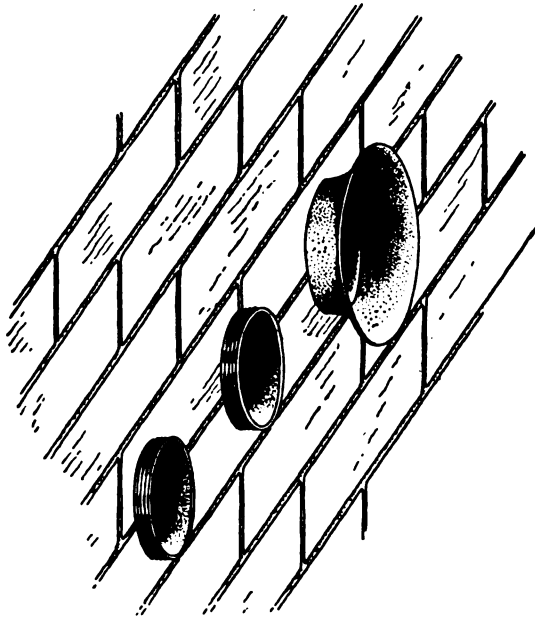


FIG. 15—FIRST TELEPHONE "DRAWING-IN" CONDUIT SYSTEM

Showing threaded ends of ducts and brass bell attachment to prevent injury to cable when drawing in.

work and to exclude water from the finished structure. Wrought-iron boiler tubes, eighteen feet in length and about three inches in outside diameter, were used for the ducts. Each length was carefully treated, at a temperature of 300 degrees Fahrenheit, with a preparation consisting chiefly of gas tar and dead oil. Eight of these pipes were laid in a formation four wide and two high, except where it was necessary to spread the pipes out to avoid obstructions. They were spaced three inches apart and were surrounded with concrete three

² Ref. (74).

inches thick (Fig. 14). The threaded ends of the pipes were laid to project about three-quarters of an inch into the manholes, or vaults, so that, when a cable was to be drawn in, a flaring brass bell could be screwed on in order to give a rounded, smooth surface over which to draw the cable, thus preventing injury to it from the sharp edge of the pipe (Fig. 15).

The construction of the manholes, or "draw boxes," as they were then termed, differed widely from present practice. A floor of tongued and grooved planks was laid over the bottom of the excavation upon

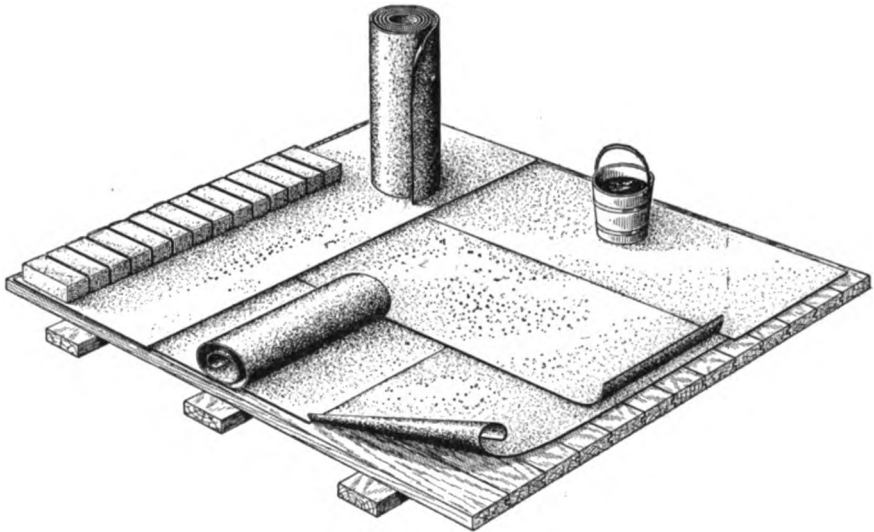


FIG. 16—FIRST TELEPHONE "DRAWING-IN" CONDUIT SYSTEM
Method of constructing manhole floor.

a thin layer of well-rammed sand. The planks were spiked to stringers embedded in the sand.

The floor was then coated with hot tar and immediately covered with a layer of tarred paper which was in turn coated with tar. A second layer of tarred paper was followed in the same manner with a third. The bottom was then covered with bricks laid flat in hot tar, the joints being afterward poured full of the tar which was allowed to flow over and cover the whole surface (Fig. 16). Upon this base the sides of the manhole were laid, two bricks in thickness. On the outside, from the bottom to the top, a course of brick was laid

on edge, half an inch from the wall of the manhole and, as the work progressed, this space was poured full of hot tar. After the covers had been placed and the manholes were otherwise completed, a last course of brick was laid in the bottom, leaving, on one side, a small sump or pocket, into which would drain any water that might collect. As the result of these precautions, Mr. Sears was able to report that "the experience of three months indicates that water . . . has been excluded."

Six cables were drawn into this subway in January or February, 1883. Four of these were made by the Western Electric Company, one by the American Electrical Works of Providence, R. I. (Phillips cable), and one by A. G. Day (Kerite cable). Two cables were also ordered from the Clark Insulated Wire Company, of Bristol, Pa. There were delays and disappointments in furnishing these latter cables and they were not completed in time for the original installation, but they were laid in April, 1883.

Mr. Vail's letter of November 15, 1882, placing the order with the Western Electric Company, read as follows:

"We shall require for immediate use in underground pipe from six to seven thousand feet of 50 conductor Patterson cable. The number of cables and their lengths I cannot give you at this time, but if you can begin their manufacture at once, I wish you would do so. I will send you the lengths in about a week and then inform you what the covering of the lead pipes shall be. The conductors to be twin wires of No. 22 gauge."

It was specified that these cables should have the conductors twisted in pairs for metallic circuits.

The American Electrical Works cable was to have from 35 to 40 copper conductors of No. 22 B. & S. gauge, rubber insulated, with heavy tin-foil covering, cabled together and covered outside with vulcanized rubber and a woven jacket well saturated with paint.

The Day (Kerite) cable was to have 36 conductors of No. 18 Birmingham gauge copper wire, covered with Kerite to 5/32 of an inch and treated with plumbago; to be cabled and wrapped with two layers of tape.

The Clark cables were to have 38 No. 22 B. & S. gauge copper conductors with rubber insulation and to be protected from induction by heavy tin-foil covering "either about each conductor or about each

layer of conductors as you prefer." The cables were to be covered with rubber cloth and a woven jacket.

All of the cables that went the full length of the subway, both lead sheathed and rubber covered, were further protected by five No. 16 galvanized steel wires, equally spaced and wound spirally about the cable with one turn in twelve inches. The object of these outside protecting wires, in the case of the rubber cables, was not to add strength nor to prevent abrasion, but to prevent the pipes from clogging when a cable was withdrawn in case the cloth covering should rot after a series of years. They also served for attaching the rope for drawing in the cables.

One of the Western Electric cables was drawn into the Franklin Street conduit. The underground run was 1,436 feet and there were five intermediate manholes. The cable was made in two lengths and spliced with a sleeve joint before being drawn in. The report states: "Owing to the increase in size and possibly to the workmanship, this joint proved defective, and when it reached the Devonshire Street manhole, it was found necessary to cut it out and make the joint over anew." About nine hours time was taken drawing this cable in.

The remaining five cables were drawn into the Pearl Street conduit, these being the 1,200-foot cables of the 1883 report. They were made and drawn in in one length. Three Western Electric cables were drawn into a single tube, and the Phillips and Day cables together were also drawn into a single tube. The reels containing the cables were set up at about the midway point of the run and the cables were drawn in, directly from the reels to the office end of the run. The remaining cable was then uncoiled upon the surface of the street (canvas having been previously laid down) in the form of a "figure eight," so that when they were hauled in there would be no twisting.

To connect with the overhead wires, supported on roof structures, the cables were carried in iron pipe, attached to a building and extending about ten feet above the sidewalk. Thence they passed up the front of the building to an outrigger on the edge of the roof. At the top of the iron pipe was screwed a brass coupling which held in place a rubber disk through which the cables passed. The small cup-like space at the top of the pipe was filled with a cement to prevent the water from accumulating.

With the beginning of underground construction came drastic legislation to remove the wires from above the streets, without regard

to the difficulties of talking over wires in cables, at that time far from being solved. In some places the poles were ordered removed within a short period of time; in others the same result was sought to be accomplished by laying a heavy annual tax on the poles. The youthful industry did what it could to meet the demand for removing the wires from the streets and the house-tops.

At Washington, D. C., in 1884, a cable 3,000 feet in length was buried in the ground. None of the wires was larger than No. 22 gauge. After it had been put into use the General Manager of the company said, "We do not propose to put any other cable down with the small conductors that we put there."³

A contemporaneous account of this work read as follows:

"The Chesapeake and Potomac Telephone Company have just completed laying an underground conduit half a mile long, for the purpose of making a practical test of underground wires for telephone purposes. A ditch 18 by 18 inches was made in the sidewalk, in which a board trough 8 by 8 inches was placed. This trough contains in all about 500 wires. Three Phillips and three Patterson cables are laid in the bottom. Fifty No. 18 office wires—some of them bare—are above the cables and ten No. 8 electric light wires above these.

"The trough is filled with asphaltum, which was poured in while hot, surrounding the wires and cables and forming a solid mass."⁴

In Brooklyn, the New York and New Jersey Telephone Company had laid six cables in the immediate vicinity of the exchange. They all ran together about 800 feet from the exchange, then opened out into a "Y," three cables running about 100 feet to Washington Street and the other three to Fulton Street.⁵ Each cable contained 50 wires of No. 20 copper and was about one and a quarter inches in diameter. A light sectional iron trough was placed in a trench excavated to a depth of about 30 inches below the paving of the street. This trough was equipped with "insulite" bridges about 18 inches apart on which the cables rested. After the cables were laid, vulcanized bitumen,

³ Ref. (39), p. 110.

⁴ Ref. (53).

⁵ *Electrical World*, December 27, 1884.

called "Bitite," was run in so as to cement the cables, bridges, and trough into a solid mass.

By the fall of 1885 considerable progress had been made in putting the telephone wires underground for short distances in the cities. In the entire Bell System, at that time, upward of twelve hundred miles of wire were underground.

In the Thirty-ninth Street Exchange, in New York City, lead-covered cables, the wires insulated with cotton and embedded in paraffin, were used. As these cables were placed in creosoted wooden boxes filled with sand, they could not be drawn out. Each cable contained from 50 to 100 wires. Five cables ran from the central office, through 39th Street to the corner of Seventh Avenue; three through Sixth Avenue to the corner of 42nd Street; and one to the corner of Sixth Avenue and 45th Street.⁶

At the Twenty-first Street Exchange, the Edison System of underground wires, made by the Electrical Tube Company, was in use. There were from 100 to 270 wires in each cable. Each wire was covered with a cotton braid treated with an insulating compound. All the wires were bunched together and placed in an iron pipe, into which asphaltum was forced, entirely surrounding the wires. The sections of iron pipe were each thirty feet in length, and two sections were connected together before laying. The pipes were painted with tar and were laid four feet under the surface with a board placed on top to protect them.⁷

The Spring Street Exchange had a Brooks System made by the Electrical Construction and Maintenance Company of Philadelphia. The wires left the office in two four-inch pipes, containing 380 conductors each, and were carried on, through pipes of various sizes down to two and one-half inches, to the several points where the wires were distributed on the poles. There was a cotton covering around each wire, and the whole number of wires to be contained in each pipe was made into a cable. After the pipes were laid in the street, three feet underground, the cabled wires were drawn into the pipes and the latter were filled with oil. The pipes rested in a wooden conduit or trough into which pitch was poured until the box was filled.⁸

Across the river, in Brooklyn, a "drawing-in" system, built of

⁶ Ref. (39), p. 98.

⁷ Ref. (39), pp. 98, 99.

⁸ Ref. (39), p. 99.

creosoted wood, was begun in 1884. This consisted of a square box, the sides, top, and bottom of one and one-half-inch plank, subdivided into pigeonhole ducts varying in number from four to ten, the divisions being made with one-inch boards. As the manholes were not very frequent, it was anticipated that trouble might be experienced in drawing in the cables. To obviate this, the ducts were made three inches high by two inches wide, and rollers were placed in the bottom of each duct for the purpose of lessening friction. This conduit was made in sections sixteen feet long, which were carted to the trench, dropped in, joined together, and the covers screwed on.⁹

The annual report of the American Company, issued in 1886, gives a concise picture of the underground situation :

"The removal of open wires from house-tops to overhead cables and to underground conduits has continued, the progress in the latter respect being especially encouraging. The system must always be a mixed one, as the final distribution of wires to the customers, and the method of reaching places where underground work would be too costly, must still be overhead ; but we think that, within a few years, in all large cities the open wires will be placed in cables above or under ground to such an extent, at least so far as telephone companies are concerned, that the overhead wire nuisance will no longer be serious.

"In New York an amendment to the law which ordered all wires in New York City and Brooklyn under ground before last November, was adopted, establishing a Commission for each of these cities with power to supervise the execution of the law, and to arrange for placing the wires under ground to such an extent as might be found practicable.

"In Brooklyn the Commission has permitted the wire companies to begin their work, and one hundred and thirty-four miles of underground wire have been placed there by the Telephone Company. In New York the Metropolitan Company in August, 1885, filed with the Commission the necessary plans and statements for an underground system, and applied for permission to prosecute the work, but so far without success, and this work in that city is at present at a standstill."

⁹ Ref. (41), p. 105.

At about this time trials were made of Dorsett conduit (Fig. 17), made of an admixture of asphaltum and sand. The material was molded, under high pressure while hot, into cylindrical sections, three feet in length and ten inches in diameter. Each section contained seven two-inch holes which were made to register when adjacent sections were joined together. After an experience of only about one year with five miles of this kind of conduit, constructed under contract for the Telephone Company in Brooklyn, the General Manager of that company stated:

"The Dorsett conduit, five miles in all, connecting Brooklyn and Williamsburgh, when completed proved to be very defective. The faults in it are due to several causes, but chiefly to carelessness in laying it in the ditch and making the joints. After

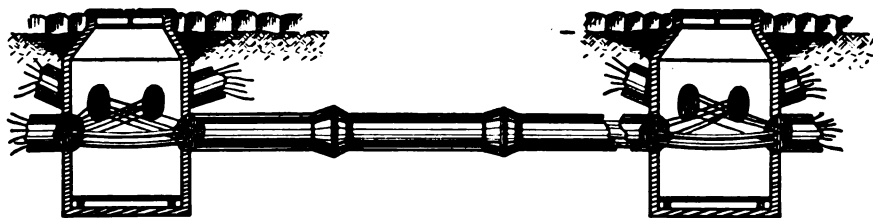


FIG. 17—DORSETT CONDUIT

Two manholes and intervening group of ducts.

a great deal of work, occupying all this year, the ducts are now reported ready for occupancy. The Dorsett material is very rough, and at the joints it squeezed through the cracks, making projections that were broken off in the process of clearing out, and brushes had to be run through to clear these pieces out. Even now the ducts are so very rough that a lead cable is badly scratched in hauling in. It was claimed this material was gas-tight and water-tight; our experience is that it is neither gas-tight, water-tight or even mud-tight, all of these things having been found in the ducts and manholes. The only explosion of gas we have had in Brooklyn was in a Dorsett manhole.”¹⁰

In Chicago, in 1886, was an underground route about a third of a mile in length, consisting of Patterson and Kerite cables drawn into

¹⁰ Ref. (42), p. 85.

Dorsett conduit. Most of the wires in the business district were in cables passing over the roofs of buildings. In the north, west, and south divisions of the city, however, where there were exchanges of about six hundred subscribers each, there had been installed, the year before, underground cables reaching from a thousand feet to a mile away from the office; and about 1,100 feet of conduit, consisting of 16 wrought-iron pipes two and one-half inches in diameter and laid in concrete, were being built to carry the cables from an existing central office to a new building. But the cable situation was unsatisfactory by reason of crosstalk, or overhearing, and the indistinctness of transmission. So serious were these troubles that an official of the telephone company in Chicago expressed his opinion at the time, as follows:

"I fear that the increasing use of cables is destroying the satisfactory character of telephone transmission. We expect this year to put down two miles and a half of Brooks oil cable throughout the central district, connecting our whole system together. When this is completed, a few months' use will show whether my fears are well founded; but I have serious doubts whether we can after this year continue further our underground extensions."¹¹

In 1887 the mileage of wire underground in the Bell System reached a figure nearly double what it was the previous year.

The annual report of 1887 stated:

"It will be noted that the number of miles of wire underground has materially increased, and we expect further large additions to the underground mileage in the current year, especially in New York, where the Subway Commission has made arrangements for the working of an underground system, which will meet the requirements of the wire companies. The legality of the plan adopted by them has been questioned in the courts, and further legislation may be needed before the work can be completed; but, as there is a strong public desire for the burying of wires to the greatest practicable extent, the necessary legislation will probably be obtained and the work go forward. This will involve a heavy outlay by the Metropolitan Telephone and

¹¹ Ref. (41), p. 99.

Telegraph Company, and the subject has been under careful consideration by the directors of that company and by our Mr. Davis; and they are prepared to put a large part of their wires into subway conduits as soon as the obstacles referred to are removed."

The underground installation in New York City was designed on the principle of keeping the electric light and power wires in conduits, or subways, as they were then generally called, on one side of each street, and the telephone and telegraph wires in subways on the opposite side of the street. A special cause of trouble encountered in New York was the steam-heating, underground system. In certain localities leaks from it greatly interfered with the ducts and cables, precluding, in such places, the use of materials of construction which would melt or soften at temperatures of about 160° to 200° Fahrenheit.

By the year 1889 most of the telephone companies were using

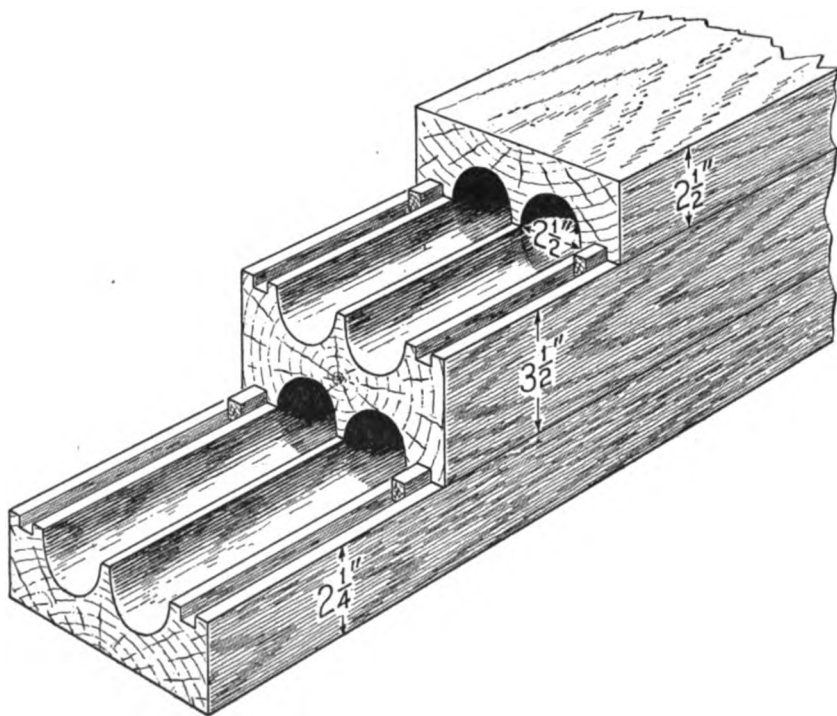


FIG. 18—MACDONALD WOODEN CONDUIT

three-inch ducts instead of the two and two-and-one-half inch sizes that had found favor in earlier years. In some cases creosoted wood conduits were made using several horizontal layers of treated wood. As is shown in Figure 18, the bottom layer of wood was fluted on its upper surface; intermediate layers were fluted on their upper and lower surfaces; and the top layer was fluted on its lower surface, so that, when assembled in the trench, they formed a rectangular structure with round holes for the cables. This was known as the Macdonald conduit. Use began to be made also of creosoted wood conduit in the form of individual ducts, called "pump logs"

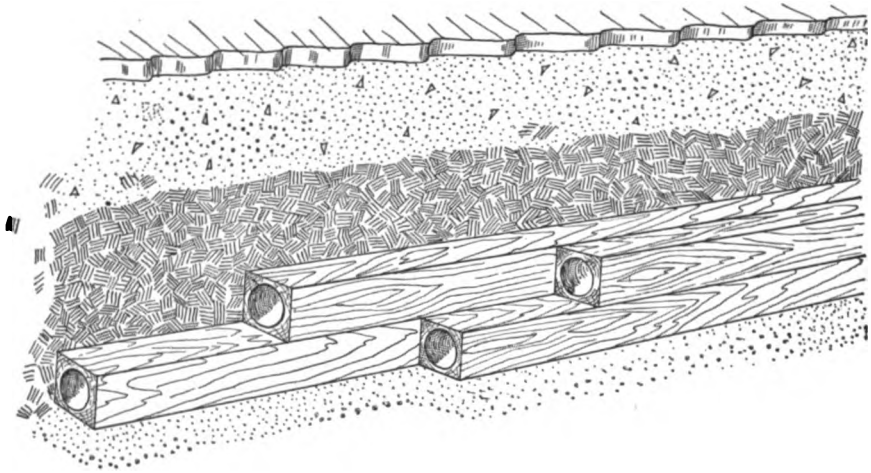


FIG. 19—CONDUIT OF INDIVIDUAL CREOSOTED WOOD DUCTS, KNOWN AS "PUMP LOGS"

(Fig. 19), each piece being several feet long and about four and one-half inches square with a three-inch round hole. Each piece was provided with a tenon at one end and a mortise at the other. These were laid, as many as were required, in any cross-sectional arrangement as to width and height. Considerable use was also made of individual pipes of sheet-iron lined with a wall of cement. These were laid in a trench and surrounded by a matrix of concrete.

At about this time, vitrified clay or glazed tile began to be used. This type of conduit was in sections ten inches square divided by a horizontal web or shelf into upper and lower compartments, each intended to provide space for three cables placed side by side. Trouble

was experienced with it, however. Although three cables could generally be placed on each shelf, any one of them, frequently, could not be withdrawn as they settled together and became jammed; also the middle shelf would break at a manhole entrance and continue to break back into the conduit. Two or three years later, conduits began to be built of another form of vitrified clay, known as "hollow brick." The material came in pieces about a foot and a half long and four

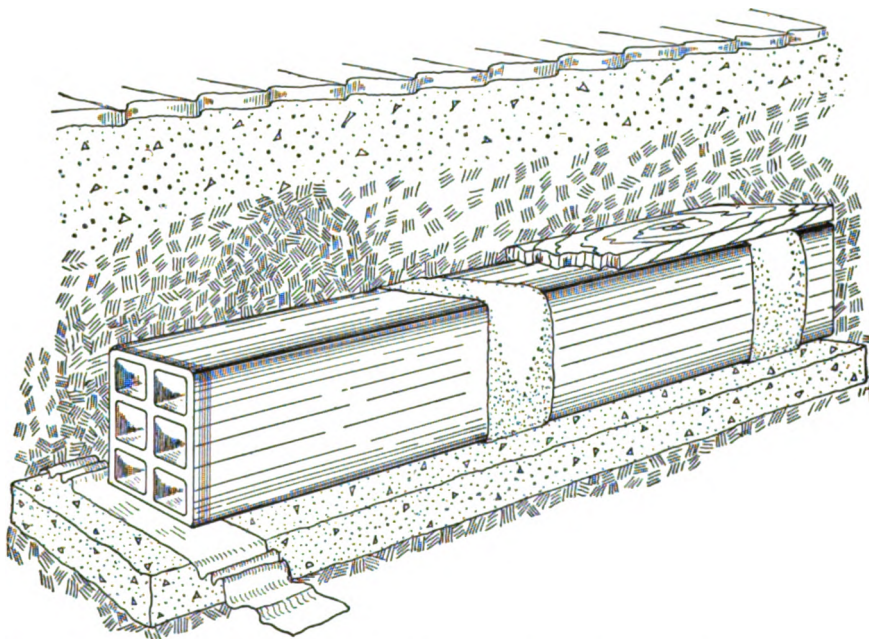


FIG. 20—VITRIFIED CLAY CONDUIT: MULTIPLE DUCT LAID ON CONCRETE BASE. JOINTS WRAPPED WITH MUSLIN AND CEMENTED. CREOSOTED WOOD PROTECTING PLANK LAID ON TOP.

and one-half inches square, with a round hole about three inches in diameter to receive the cable. These hollow bricks were laid in cement mortar and the entire structure was then embedded in concrete. Shortly, another form of vitrified clay, called the "multiple duct," came into use (Fig. 20). In this type of conduit a separate square hole was provided for each cable and the sections were generally made with either four, six, or nine holes. Where more ducts were required, two or more sections of "multiple duct" were laid, one

above the other or side by side, as circumstances required. Vitrified clay ducts have since become the principal type of underground construction employed in telephony.

Further progress in putting the wires underground leads us to a description of the improvement in the cables, and this will form the subject of the next chapter.

CHAPTER IX

IMPROVING THE TELEPHONE CABLE

As late as 1890 the entire amount of underground telephone wire in ten of the principal cities in the United States was equivalent to less than two days' output of the largest cable factory in America at the present rate of manufacturing. Another picture of the small amount of telephone cable in the early years is given by the statement of Mr. Sargent, the General Manager of the New York and New Jersey Telephone Company, made in 1887:

"We believe it economical and desirable to have employees capable of doing all kinds of cable work, including joints and terminals, and have two men under instruction for that purpose."¹

As is apparent from the preceding chapters, there was much diversity in the types of cables used before 1887. The need for standardization was becoming more and more apparent and, in September, 1887, some leading telephone executives and engineers met, at the invitation of The American Bell Telephone Company, for the purpose of discussing the experience which had been obtained thus far with cables and making an effort to define the qualities that were needed for good work. There was general agreement that any exchange that contemplated a change to the metallic circuit system within the next two or three years should unquestionably adopt "the twisted double-wire arrangement."

As a result of this conference, specifications for telephone cables were prepared and issued in 1888. They provided for the use of No. 18 B. & S. gauge * wire, covered to an outside diameter of one-eighth of an inch with not less than two wrappings of cotton. The conductors were to be twisted in pairs with a three-inch lay and formed into a core with reversed layers. The spaces in the core and between the core and the pipe were to be filled with an insulating material. The

¹ Ref. (42), p. 87.

* 40 mils in diameter, weighing about 26 pounds per wire-mile.

sheath was to be of an alloy of 97 per cent lead and 3 per cent tin, and about one-eighth of an inch in thickness. For the electrostatic capacity, a maximum limit of .20 microfarads per mile was set, each wire to be tested against all the others grounded. These requirements were such as to permit 52 pairs of wires to be placed in a cable having an outside diameter of two inches.

The next important step in the development of cables was the transition from cotton-insulated, filled cable to paper-insulated, dry-core cable. This fundamental move can be attributed to no particular invention; it was a matter of gradual evolution and accumulated experience. The omission of the filling or sealing material came about quite naturally as soon as experience had shown that lead sheaths could be so applied as to be trustworthy in excluding water.

Thereafter, the need for an insulating filling ceased to exist.

As early as 1880 Mr. Patterson, cable expert of the Western Electric Manufacturing Company, had tried omitting the oil filling of the Brooks System and, later, he went further in the direction of dry-core cables by omitting the paraffin that was used with cotton-insulated wires, in certain special instances where, for short lengths underground, the cables were exposed to a high temperature from neighboring steam pipes.

The extrusion of a lead sheath directly upon a cable core, instead of drawing the core into a length of previously manufactured pipe, was no novelty at the time when this process began to be widely used in the manufacture of telephone cables. David Brooks, Jr., in Philadelphia, sometime in the early "eighties," made small lead-covered cables with the sheath formed about the core, and machines for that purpose were in use to some extent both in this country and in Europe.

While investigating the state of the art among lead-pipe manufacturers and the makers of lead presses, in 1885, John A. Barrett, who was then working on Bell System cable problems, made the acquaintance of John Robertson, an inventor and maker of hydraulic lead presses, in Brooklyn, N. Y. At that time Mr. Robertson had, in his shops, a lead press of his own invention, which he was using to cover single electric-light wires with a thin sheet of lead. Although this machine was a small one, its capacity being limited to a pipe about half an inch in diameter, Mr. Robertson was confident that he could build a machine, operating upon the same principle, that would work just as well for cables up to two inches or even three inches in diam-

eter. As Mr. Robertson's shops were in Brooklyn, the New York and New Jersey Telephone Company, early in 1886, arranged for him to build and erect a lead press capable of extruding a pipe two inches in diameter; and arrangements were also made for Mr. Barrett to take charge of the work of constructing, at the Robertson shops and convenient to the lead press, drying ovens and a tank containing the mixture of resin and oil that was used for sealing the cable against the entrance of water through defects in, or injury to, the pipe. Cable cores made up of cotton-covered wires were bought from wire manufacturers and delivered to the Robertson shops where they were dried in the ovens and boiled in the tank of sealing mixture. From the tank, each piece was run through the lead press, where it received its covering of lead-tin alloy in a continuous length.

With the object of reducing the specific inductive capacity and the cost of wires in cables, experiments were carried on with manila paper as a covering for the wires, without much success until a quantity of wire, covered with manila-paper tape laid on spirally with overlapping edges, was obtained. This wire was made into a cable core and put through the regular process of drying in the oven, dipping in the hot sealing compound, and covering with the lead sheath. Electrical measurements showed an important improvement in the reduction of the electrostatic capacity. Inspection of the cable indicated that this was due to the fact that the sealing mixture had penetrated imperfectly into the layers of paper, which remained, to a considerable extent, dry, the spaces being filled with dry air. In the next step taken, instead of boiling the cable core in the mixture, it was run directly from the drying oven into the lead press, passing through a trough containing some of the sealing mixture.

From this procedure there resulted virtually a dry-core cable with only a small quantity of the mixture on the outside of the core. This was intended to serve as a lining to the sheath and to seal any imperfections that might occur in the latter. By this step a further considerable gain was made in the uniformity of the cable and in the reduction in its electrostatic capacity.

The entire elimination of the sealing mixture—except as a plug for a short distance at the ends of each length—was the next step. These steps were by no means taken in rapid succession. Several years were occupied in improving the lead press and the methods of preparing and applying the lead-tin sheath. The latter part of the

year 1889 was reached before it became clearly recognized that the sealing mixture detracted from the desired electrical properties of telephone cables and that trustworthy cable sheaths could be produced in large quantities.

But it was one thing to make dry-core cable and quite another to assume the responsibility of embarking upon its extensive use. Any widespread failure of the sheaths to maintain their integrity, with the consequent admission of water to the unprotected core, would have resulted in a catastrophe to the plant and the service. So marked a case was it of putting all the eggs in one basket that the greatest caution had to be exercised. In 1889 it was felt that experience had not yet fully established the ability of the sheath to exclude water unaided by any filling material.

In order to gain further experience, two long cables were laid in Philadelphia, in 1890, without filling for the greater part of their lengths.

The insulating materials were sisal and dry cotton. At about the same time a number of dry-core, paper-insulated cables were placed in service in New York City. It is difficult to appreciate the courage that was needed to sponsor these early installations; in fact, so much unsettlement of mind existed on the subject that it was not until 1891 that it was felt that enough experience had been obtained to retire cotton-insulated, filled cable into disuse.

In the early use of lead-covered cable, placed underground, considerable trouble was experienced from corrosion of the sheath, particularly where the cables were placed in wood ducts which had been treated with wood creosote, resulting in the exposure of the sheaths to the action of acetic acid.

Some of the early cables had sheaths of unalloyed lead, and these proved readily susceptible to attack from this source. Also, lead alone did not possess the tensile strength required to enable the cables to be drawn into ducts and otherwise handled.

As early as 1882, to overcome these difficulties, there began to be used sheaths in which the lead was alloyed with three per cent of tin. This considerably increased the tensile strength and, at the time, it was felt that it retarded the rate at which the chemical action took place. So greatly was the corrosion of the sheath feared that, in 1889, it was specified that the pipe should be thoroughly coated with asphalt and, in addition, a protecting jacket should be provided on the out-

side, consisting of at least two wrappings of tape put on in reversed layers and thoroughly impregnated with asphalt. About the only other change of importance made in 1889 in the standard cable specifications was to reduce the allowable electrostatic capacity from .20 to .18 microfarads per mile.

The next two years witnessed the establishment of paper insulation as the standard for telephone cables. In the standard specifications of 1891, the size of conductor was reduced from No. 18 to No. 19 B. & S. * gauge, and the electrostatic capacity requirement was made .085 instead of .18 microfarads per mile, thus definitely settling on the use of dry-core, paper-insulated cable.

At that time grave fears existed as to the lasting qualities of the paper and the ability of the entire cable to withstand the necessary handling during installation without experiencing injury. As experience accumulated, it was collected and analyzed and a programme of tests and experiments was carried out in the Bell System laboratories. Many drafts of specifications were prepared, culminating in the specifications for the so-called "Conference" type of dry-core cable which was issued by The American Bell Telephone Company in May, 1892.

The "Conference Standard" provided for conductors of No. 19 B. & S. gauge and an average electrostatic capacity of .080 microfarads per mile, each wire being measured against all the rest and the sheath. On the basis of these specifications, one hundred pairs of wires were to be placed in a pipe whose outside diameter was not to exceed two and one-half inches. The paper was wrapped loosely about the wires. In some cases two spiraled wrappings of paper tape, each about five-eighths of an inch in width, were used, and in others one or two paper tapes were placed lengthwise along the wire, rolled about it into a tubular covering, and held in place by spiraled twine.

To satisfy the demands of the growing business, cables containing more pairs of wires were needed, and, as the result of added experience in manufacturing and installing the cables, and by permitting the electrostatic capacity to be increased somewhat, it became practicable, in 1895, to adopt specifications for a cable, with No. 19 gauge conductors, having 150 pairs in a sheath two and five-sixteenths inches in outside diameter. The step from this to cables with 200 and 220 pairs was a short one.

* Number 19 is about 36 mils in diameter and weighs about 20 pounds per wire-mile.

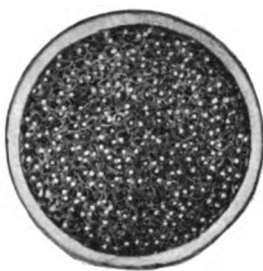
Further progress was to come with a decrease in the size of the cable conductors. In 1899 it was foreseen that only in that way could cables be obtained having the greater number of pairs that was beginning to be urgently required to meet conditions of exchange growth in the larger cities. Following the trial of some experimental "fine-wire" cables having conductors of No. 22 B. & S. gauge,* the use was begun, in 1901, of 400 pair, No. 22 gauge cables, which was followed, the next year by cables containing 600 pairs of No. 22 gauge wires. In connection with the introduction of "fine-wire" cable, economic studies were made to determine the proper limits for its use in subscribers' lines and in interoffice trunk lines, so that suitable standards of transmission should be maintained in the most economical manner.

This book, dealing with the beginnings of telephony, is not a suitable place to recount the many developments and improvements which have taken place, in the cable art, within the last generation, but it has seemed proper, in order that the early cable art may be visualized in its relation to what has since been accomplished, to include Figures 21 and 22; the first showing, on the same scale, cross-sections of cables illustrating some of the principal stages in the entire development of paper-insulated cables used in the Bell System, and the second showing, in graphic form, a measure of the savings that have resulted from this work.

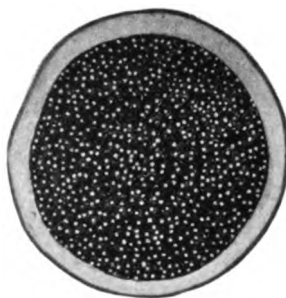
Turning now to a consideration of the cables employed in inter-city and toll-line use, the situation prior to the use of loading coils will be briefly reviewed.

The idea being prevalent that open-wire circuits "talked better" in wet weather, when the insulation was low, than in fair weather, when the insulation was high, pioneer experimenters sought to improve the transmission efficiency of cables by introducing artificial electrical "leaks" along the circuit. As early as 1880 it is said to have been suggested by Mr. Watson, in the case of a seven-conductor rubber-insulated cable about seven miles in length, that if the conductors were connected through resistance coils to earth at frequent intervals, it might be possible to talk more easily over them. Resistances were prepared which were put in at intervals of one thousand feet. They were changed from as high as 40,000 ohms down to quite low values. It was concluded, at that time, that the use of these

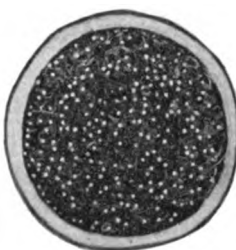
* 25 mils diameter, weighing about 10 pounds per wire-mile.



1895
152 Pairs
No. 19 A.W. Ga.



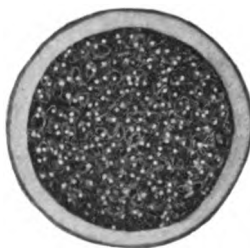
1901
303 Pairs
No. 19 A.W. Ga.



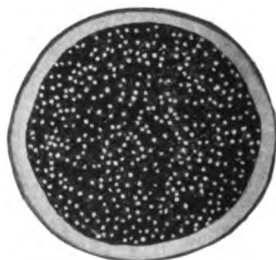
1895
122 Pairs
No. 19 A.W. Ga.



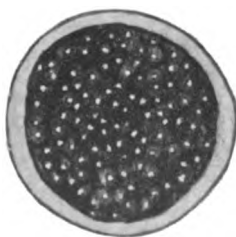
1901
404 Pairs
No. 22 A.W. Ga.



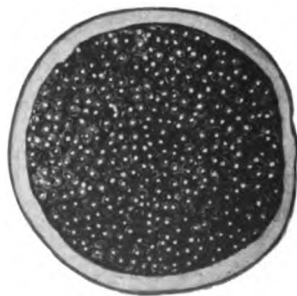
1892
100 Pairs
No. 19 A.W. Ga.



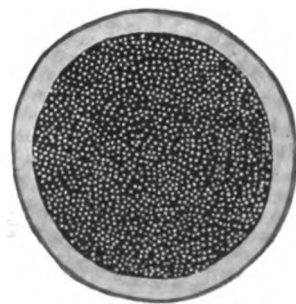
1896
208 Pairs
No. 19 A.W. Ga.



1888
50 Pairs
No. 18 A.W. Ga.



1896
180 Pairs
No. 19 A.W. Ga.



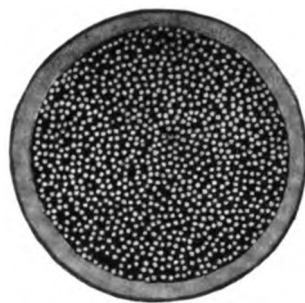
1902
606 Pairs
 No. 22 A.W. Ga.



1912
909 Pairs
 No. 22 A.W. Ga.



1914
1212 Pairs
 No. 24 A.W. Ga.



1918
455 Pairs
 No. 19 A.W. Ga.

FIG. 21—Cross-sections of actual cables, varying in diameter from about two and five-eighths inches, showing principal stages in the development of paper-insulated cable used in the Bell System. These were the largest cables being made as of the dates indicated.

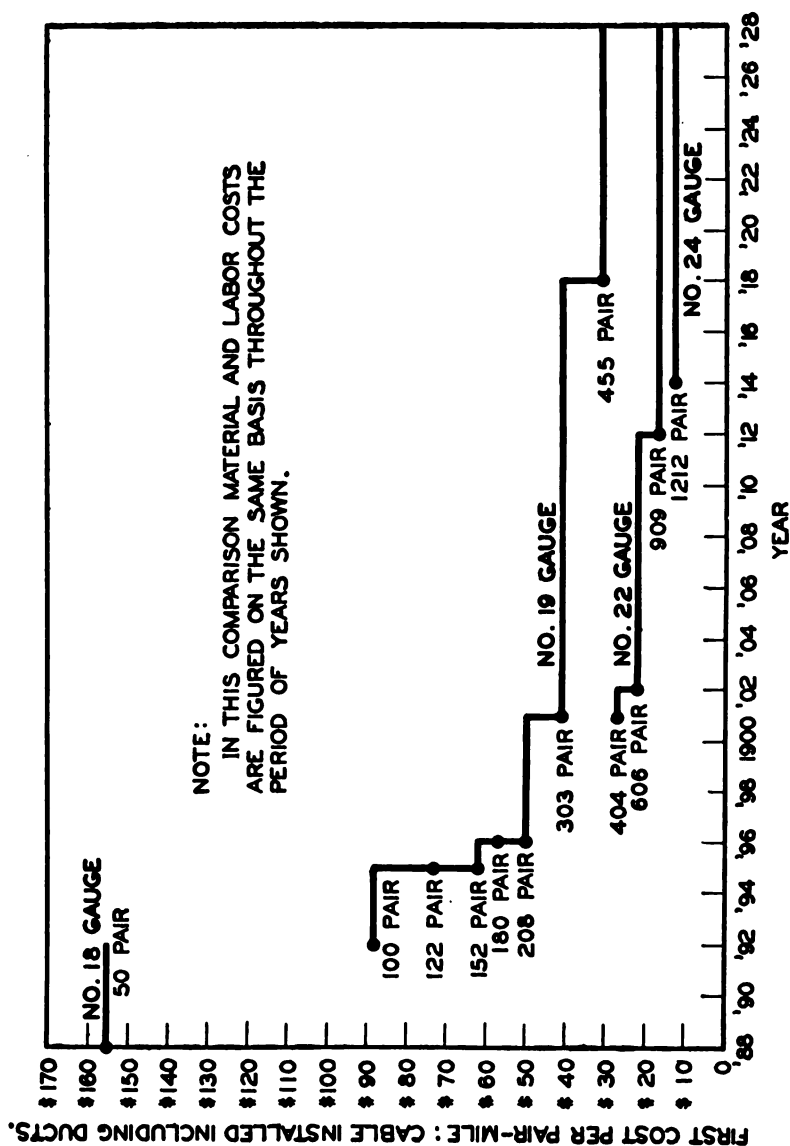


FIG. 22—ECONOMIC CHART SHOWING REDUCTIONS IN THE COST OF A MILE OF CIRCUIT IN FULL-SIZE CABLE RESULTING FROM THE DEVELOPMENTS ILLUSTRATED IN THE PRECEDING FIGURE

resistances either had no effect on transmission or diminished the ability to talk through the cable. It was, therefore, the case that, until the development of the loading principle, high transmission efficiency in the longer cables could be attained only by decreasing either the resistance or the electrostatic capacity of the cable circuits, or both. This meant the use of large conductors of copper, with the wires of each pair kept as far apart as practicable by means of the paper insulation, the amount of paper being reduced to a minimum in order that the greatest possible proportion of the space between the wires of a pair might be occupied by nothing but air. It was discovered that the two factors controlling the transmission efficiency of the cable circuits—resistance and electrostatic capacity—were of substantially equal importance, and the reciprocal of the square root of the product of these two factors was used as a measure of cable transmission efficiency.

In 1898 a cable nearly eight miles in length was placed extending from Boston toward Lynn, Mass. This cable contained 30 pairs of conductors in a sheath two and three-sixteenths inches in outside diameter. The wires were No. 16 B. & S. gauge.* The mutual capacity between the wires of a pair in this cable was about .042 microfarads per mile. Carefully conducted tests showed this cable to have a transmission efficiency about twice that of No. 19 gauge cable. Shortly after this a 30-pair cable having conductors of No. 14 B. & S. gauge † in size, insulated with a double wrapping of paper, was placed from Boston to Wakefield, Mass.

In 1899 plans were in the making for an underground, suburban trunk-line system centering in New York City, and in 1900 the installation of cables two and one-half inches in outside diameter, containing 50 pairs of wires No. 13 B. & S. gauge ‡ in size, was begun in connection with this system.

In 1901 there was installed between Boston and Forest Hills about five and one-half miles of a cable of so novel a type as to warrant a brief description. It contained 30 pairs of No. 14 B. & S. gauge conductors, each covered with a thin coating of shellac to which, while the shellac was sticky, was applied coarsely granulated cork, and over this was placed a paper wrapping, laid on longitudinally, and held in place

* 50 mils in diameter, weighing over 40 pounds per wire-mile.

† 64 mils in diameter, weighing about 65 pounds per wire-mile.

‡ 72 mils in diameter, weighing about 82 pounds per wire-mile.

by a binding string. The electrical properties of this cable were satisfactory, but not so much could be said for its behavior while being handled and spliced. It was a failure.

In the latter part of 1901 development work was undertaken on a cable destined to connect Boston with the cities of Lowell and Lawrence, a second cable of the same type being also planned to connect Boston with Salem, Mass. As the distance by the underground route from Boston to Lowell was about twenty-eight miles, a cable of high efficiency was required. Conductors of No. 13 B. W. G. * were employed. These wires approximated in size those used on overhead lines. The low mutual electrostatic capacity which was desired was only attained after development work had shown that the way to success lay in making what was, at that time, a new departure by largely increasing the ratio of air to paper in the wrapping surrounding each wire and also in increasing the length of twist of the pairs.

In the struggle to obtain low electrostatic capacity, which was going on at this time, the cable cores were becoming softer and softer to the very limit of practicable handling in reeling and installing. This particular cable, due to its softness, flattened so much on the reel that, when it was pulled into three-inch wooden ducts, the aperture of the duct served as a die to restore the cable from an elliptical shape to approximately a circular section. It was found possible to place 40 pairs of wires in these cables.

The discovery of the principle of loading (Chapter X) served to make unnecessary the installation of any more of these cables with very large conductors. Efforts were at once directed toward developing loading coils having the requisite electrical characteristics, so that, by applying them to cable conductors of moderate size, transmission efficiencies even higher than those attained with the large conductor cables could be realized.

As has already been stated, the sheaths of the cables used in the Bell System from an early date contained about three per cent of tin alloyed with the lead. This alloy was considerably higher in breaking strength than unalloyed lead. For aerial cables, the use of the alloy was particularly important as it greatly reduced the crystallizing and cracking of the sheath which experience had shown to occur where unalloyed lead was used. About 1907 development work was undertaken looking to the discovery of a new alloy that should be at least

* 95 mils in diameter, weighing about 144 pounds per wire-mile.

as satisfactory as the lead-tin alloy and less expensive. Laboratory experiments and field trials were carried on over a period of four or five years, covering a wide range of alloys. Consideration was given to the admixture with lead of antimony, bismuth, copper, nickel, and tin in binary and ternary alloys of different proportions. Specimens were tested for tensile strength, and for their ability to withstand bending, vibration, and chemical corrosion under exposure to many reagents likely to be found in the soil. Full-sized cables, with their sheaths made from different alloys, were repeatedly pulled in and out of ducts; and their behavior, in comparison with sheaths of the then standard lead-tin alloy, was carefully observed. Other test cables were installed on bridges and elevated-railway structures in order that their ability to withstand continued vibration under practical conditions of use might be observed. The work resulted in the adoption for cable sheaths of a new alloy consisting of about one per cent of antimony alloyed with the lead. This was adopted for underground cables early in 1912 and for aerial cables about a year later. By means of this alloy many millions of dollars have been saved.

This general account of early cable development and use would be incomplete without some reference to submarine cables. In a previous chapter mention has been made of the early use of gutta-percha and oil-insulated wires for this purpose. It is interesting to note the following, in a letter of Mr. Watson, written in March, 1880:

“The attempt has been made to converse through the Atlantic cable, but it was unsuccessful, and at present the scientific obstacles appear insurmountable.”

The *Electrical World*, July 14, 1883, stated:

“An interesting experiment in cable telephony has lately been reported to us. It was made on June 10 by Messrs. Theodore N. Vail, of the American Bell Telephone Company, W. H. Eckert, J. A. Seely, both of the Metropolitan Telephone and Telegraph Company, and Mr. Ladd, of San Francisco, Cal. Five submarine cables, each one mile in length, crossing the North River between New York and Jersey City, were connected together, making a total length of five miles of cable. This was placed in circuit with 106 miles of aerial wire, making a total of 111 miles. Conversation was carried on with the greatest ease,

and without the least interruption from induction or retardation. In the experiment, Blake transmitters, with two cells of battery for each, were used, in connection with Bell receivers."

The August 16, 1884, issue of the same paper stated:

"The Sunset Telephone and Telegraph Company, of California, has laid across the bay at San Francisco to Oakland, about four and one-half miles of a seven-conductor, gutta-percha insulated submarine telephone cable. This cable was furnished in October, 1883, by the Bishop Gutta-Percha Works, of New York City."

Following the gutta-percha cables, rubber compounds were generally used as the insulating materials in submarine cables for several years. As early as 1889, however, a Patterson cable had been laid between Norfolk and Portsmouth, Va., as, in that year, it was reported to have deteriorated considerably due to having been pulled out by anchors three times.

When paper insulation first began to be used in submarine cables, and for a considerable time thereafter, the entire core was filled with a bituminous compound. This was not only for the purpose of excluding water at the point where an imperfection of the sheath might occur, but also to prevent the water from penetrating a considerable distance into the cable in the event of an injury to the sheath. The sheaths of the larger submarine cables were made about 25 per cent thicker than the sheaths used on underground cables. A heavy armor of galvanized steel wires nearly a quarter of an inch in diameter was placed over a covering of several layers of jute served around the sheath. Outside of the armor wires, two wrappings of hemp were applied and the hemp was thoroughly saturated with a preservative compound consisting of a mixture of mineral pitch and fine sand. The completed cable was treated with a liberal coating of whitewash to prevent the turns from sticking to each other on the reel.

Experience having demonstrated the reliability of the lead sheath in excluding moisture, dry-core, paper-insulated submarine cables came into use as early as 1899.

At least as early as 1900, submarine cables began to be used which were protected by two lead sheaths, one placed over the other, without the covering of armor wires. It was thought that a defect in one of

the sheaths would be unlikely to come opposite or near to a defect occurring in the other. This type of submarine cable was used for several years at deep water crossings where disturbance by anchors was unlikely to occur, and where the cable, by its weight, could embed itself in the mud.

It is interesting to observe that in the small and crude cables, used in lengths of only a few hundred feet, at the beginning of the business of giving telephone service, wires as small as No. 26 gauge were sometimes used. As the lengths of cable increased, transmission considerations demanded larger and larger wires in exchange cables until No. 18 gauge became the standard. Then the tide set in the opposite direction, leading back again to the use of finer and finer wires. The important plant economies which have resulted from this movement would not have been possible, had it not been for improvements in many other parts of the telephone plant, such as transmitters, receivers, coils, and switchboard circuits and apparatus.

CHAPTER X

THE BEGINNING OF LOADED LINES

THE history of loaded telephone lines dates from the year 1900, when Professor M. I. Pupin, of Columbia University, was granted patents* dealing with the reducing of the attenuation of electrical waves. While this is not the place to review at any considerable length the labors of those who, before Pupin's invention, had worked in this direction, a brief summary of the prior art is needed by way of introduction, and this was clearly presented by Bancroft Gherardi in a paper before the Twenty-eighth Annual Convention of the American Institute of Electrical Engineers, at Chicago, June 28, 1911, from which the following extract is taken:

"The year 1900 may be considered to have marked the beginning of a very important period in the development of telephony. For some time prior to that date it had been known to those who gave study to the matter that the transmission efficiency of long telephone circuits would be improved by increasing the uniformly distributed inductance of the circuit. This knowledge, however, did not lead to any direct commercial results, for the reason that no one was able to point out any practical method of increasing the distributed inductance of a telephone circuit without bringing in difficulties of one kind or another which were fatal.

"This apparently insuperable difficulty in obtaining improved results by the use of distributed inductance directed the attention of the mathematicians and physicists to the question of whether the results sought for might not be attained by the use of inductance coils placed at intervals in the circuit instead of by undertaking to distribute the inductance uniformly along the circuit.

"Vaschy, Heaviside, and others either suggested or unsuc-

* U. S. Patent No. 652,230, issued June 19, 1900, application filed December 14, 1899.

U. S. Patent No. 652,231, issued June 19, 1900, application filed May 28, 1900.

cessfully tested the insertion of self-induction in coils on actual lines as a means of increasing their transmission efficiency. No practical results followed from their work and no actual progress was made in the matter of using lumped inductance to improve the transmission efficiency of telephone circuits until the year 1900, when the patents of Professor M. I. Pupin, dealing with the reducing of attenuation of electrical waves, were issued. Professor Pupin and Dr. George A. Campbell, who had also worked on this problem, have published several papers dealing with it. These authors discuss fully the mathematical theory of improving the transmission efficiency of telephone circuits by means of placing thereon inductance coils at intervals. The papers referred to, establish the fact that inductance in coils spaced suitably along a telephone circuit will produce the same effects as uniformly distributed inductance and show us how to suitably locate these inductance coils. The matter of suitably spacing the inductance coils is of vital importance and must be kept in mind because the spacing of the inductance coils is the key to the use of lumped inductance, and it is from the failure to establish this fact and give due weight to it that the earlier workers failed."

Speaking in the same vein, Past-President John J. Carty, of the American Institute of Electrical Engineers, on the occasion of the presentation of the Edison Medal to Dr. Pupin February 18, 1921, said:

"Before he did his work it was well known that inductance in a telephone line, when uniformly distributed, tended to have a beneficial effect, and it had been suggested that that inductance might be put into the line in lumps, and that might make an improvement. That was tried by many, and it failed. Inductance, put into the line, unless it is put in intelligently, instead of aiding transmission, hinders it; in fact, prior to the work of Dr. Pupin, we had succeeded in creating great improvements in our telephone line by removing all of the inductance from the line as far as possible. Now comes along Pupin with a very wonderful and remarkable invention, and he tells us to put our inductance back into the line, put it in in the form of lumps, but to take care to put it in strictly in accordance with the rules which he laid down in his

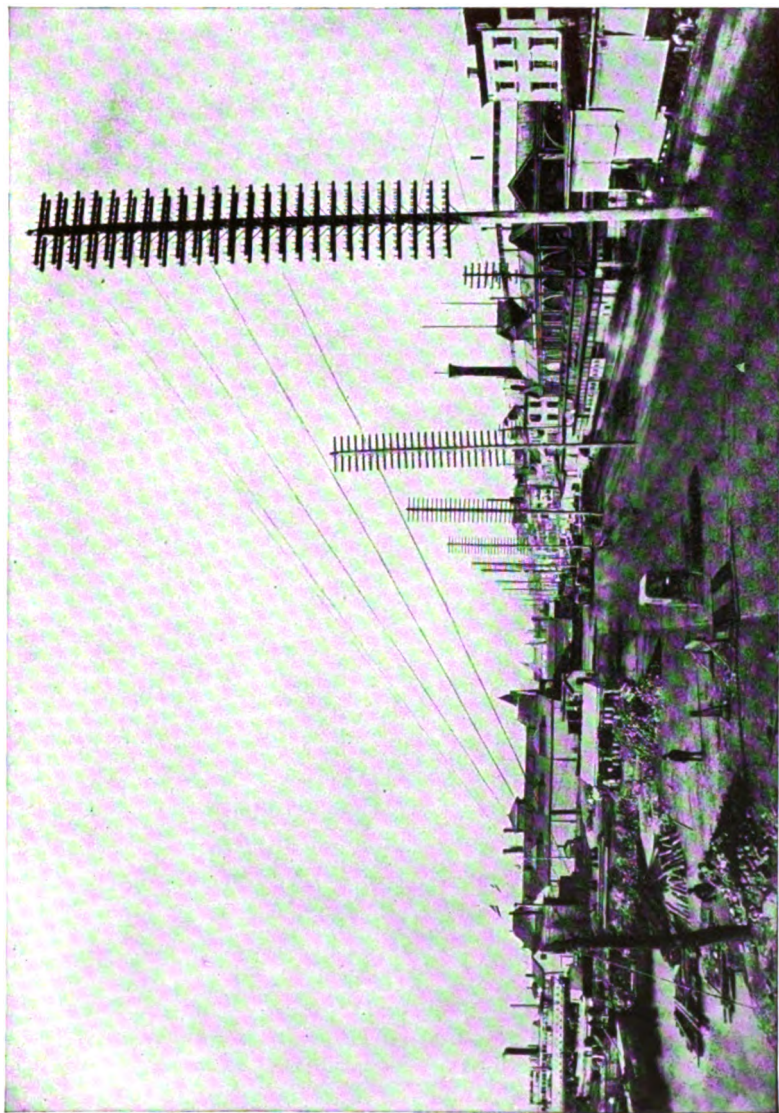


FIG. 23.—Pole line on West Street, New York City, used to carry long-distance wires extending to Boston and Buffalo. Erected in 1887.

patent, and these rules require, among other things, that the coils be spaced not so many per mile, but so many per wave length."

The term "loading" comes from the mechanical analogy of a weighted or "loaded" string, the study of which was utilized in developing the theory of electrical loading. As regards its capabilities for transmitting electrical waves, a non-loaded electrical circuit may be likened to a long, light rope or string, attached immovably at one end and free to be moved up and down at the other end, so far as its capabilities for transmitting mechanical waves or undulations are concerned. If the free end of such a rope be moved up and down, rhythmically, it will be difficult, due to the limpness of the rope, to cause very much vertical motion or displacement of the rope at a point distant from the free end.

If, however, a heavy rope be used, or if a series of small weights be placed at regular and frequent intervals along the light rope, a greater displacement can be caused at a point distant from the free end, due to the greater mass of the rope.

The heavy rope is the analogue of an electrical circuit having uniformly distributed inductance; the light rope with evenly distributed weights is the analogue of an electrical circuit loaded with lumped inductance.

The mechanical loading reduces the dying out of the waves in the rope, and the analogous electrical loading reduces the attenuation of the waves of speech current in the telephone circuit. It makes the telephone line a better path for electrical undulations. To indicate the practical value of loading, it may be stated that, under favorable conditions, a long loaded cable circuit can be made to conduct voice-frequency currents as well as they would be conducted by a non-loaded cable circuit of conductors weighing about eight times as much.

Dr. Pupin received many honors for his discovery including the Hebert Prize, awarded to him in 1916 by the French Academy of Science, "for his method of mathematical analysis of electrical circuits which is today recognized as classical, and for his discovery and inventions in electric resonance, the tuning of electrical circuits, and the loading of telephone lines." He has received the homage of telephone men and of the scientific world.

As has already been stated, Dr. George A. Campbell had also worked on the loaded line problem. On March 5, 1900, he had filed

an application for a patent in the United States Patent Office, which was placed in interference with the patent of Professor Pupin. The Examiner of Interferences awarded priority to Pupin and, on appeal, the Board of Examiners-in-Chief, on April 6, 1904, affirmed the decision. They found that Professor Pupin had disclosed his invention as early as March 22, 1899; and that Dr. Campbell's date of conception was April 5, 1899.¹ On the occasion of receiving the Edison Medal for his discoveries, Dr. Pupin courteously made reference to "George Campbell . . . who certainly would have made the invention if I had not made it." Dr. Pupin's patents were purchased by The American Bell Telephone Company. Loading was first applied, commercially, under Campbell's direction, to circuits in a cable extending from Jamaica Plain to West Newton in the suburban district of Boston, the loaded circuits being placed in commercial service during May, 1900. In that installation it was necessary to use air-core coils, as suitable iron-core coils had not then been developed. The problem of designing and producing coils of the iron-core type engrossed the attention of some of the most highly trained mathematical physicists of the American Company and of the Western Electric Company during the years immediately following the discovery of the loading principle. While the development and improvement of loading coils has continued and is still in progress, the early work was particularly strenuous, due to the novelty of the problem and the importance of being able to take advantage of the economies of loading at the earliest practicable moment. In the course of his Edison Medal address, Dr. Pupin said: "I must also acknowledge that in the development of that invention the American Telephone and Telegraph Company and the Western Electric Company have done wonders. We could have lectures every evening for a year to describe all the work which they have done and done most beautifully." It was not until 1901, however, that toroidal iron-core coils were made which were suitable for use on telephone cable lines.

In 1902 the loading of a cable extending from New York City to Newark, N. J., a distance of about ten miles, was successfully accomplished. This was a No. 19 gauge cable containing 200 pairs of wires, 49 of which were loaded at the outset. In the following year, 1903, a ninety-pair, No. 16 B. & S. gauge loaded cable was installed between Boston and Brockton, a distance of about twenty miles. The

¹ Ref. (58).

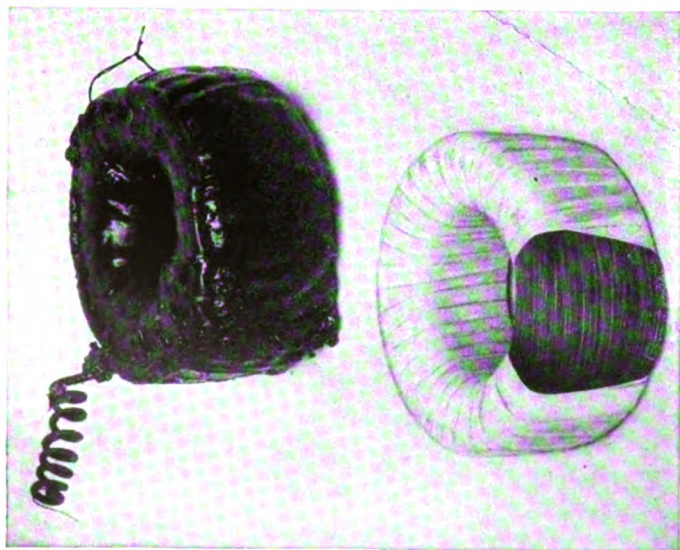


FIG. 24

FIG. 24—Cable loading coil of the type used in 1904. Complete coil above; wire core below. Diameter of core wire, four thousandths of an inch.

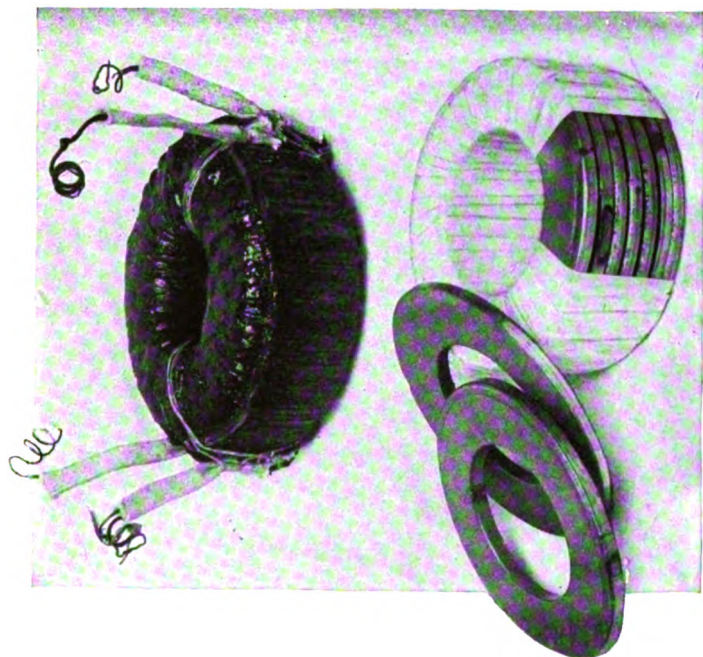


FIG. 25

FIG. 25—Cable loading coil first used in 1916. Complete coil above; iron-dust core and two extra core rings below.

notable thing about this cable was a novel method of transposing the circuits with reference to each other, which resulted in the cable being remarkably free from crosstalk.

These earliest instances of the use of loaded cables were quickly followed by the installation of many others, both for long interoffice trunk lines and for bringing open-wire toll lines into cities. In New York City loaded cables more than fifteen miles in length replaced the famous West Street pole line (Fig. 23), built of Norway pine poles 90 feet in length, some of which carried as many as thirty ten-pin crossarms. Cables for use with the longest open-wire lines contained No. 13 B. & S. gauge conductors. To meet less severe transmission requirements No. 16 and No. 19 gauge wires were used.

In 1904 a ninety-pair, No. 16 gauge loaded cable, forty-four miles in length, was placed between Boston and Worcester. Soon most of the largest cities had loaded cables, and additions were constantly being made.

It was soon realized that the developments in the art of loading were unfolding the possibility of placing, in cable, important groups of circuits connecting cities separated from each other by distances of one hundred miles or more. By 1905 there was, in operation, a loaded cable extending from New York about twenty miles in the direction of Philadelphia. So rapidly did the art advance that in the following year an underground loaded cable, having No. 14 gauge wires, was working successfully between those cities.

The annual report of the American Telephone and Telegraph Company of 1914 briefly summed up the situation as follows:

“By 1911 our experiments, researches, and improvements in manufacture had so advanced that we were enabled to design an underground cable, capable of giving a satisfactory conversation between Washington and Boston.

“By 1912 a section of this new cable was laid from Washington to Philadelphia, there connecting with the earlier type of cable to New York.

“During 1913 a section of the new cable was laid between New Haven and Providence, connecting at New Haven to an earlier type of cable extending to New York, and connecting at Providence to an earlier type extending to Boston.

“While talking the entire distance from Boston to Washing-

ton was impossible through the old types, yet by using the underground in connection with the overhead, the seaboard cities from Washington to Boston could be no longer isolated by storms destroying the overhead wires."

Loading coils of the air-core type were placed in service on open wires on the Bedford-Brushton line of the American Telephone and Telegraph Company on July 2, 1900. These air-core coils for open-wire lines were large affairs requiring boxes of considerable size to contain them. These boxes were mounted between the crossarms, on the poles, and were known, in the parlance of the linemen, as "bug traps." Until the development of a successful type of telephone repeater, there was a large use of loading coils on open-wire lines. When the transcontinental telephone line was opened in 1915, it was equipped with loading coils, spaced eight miles apart all the way from New York to San Francisco. In later years, however, the loading coils have been removed to a large extent from the open-wire lines.

In solving the problem of crystallizing the intellectual concept of loading into practical loading coils that could be used by the regular construction and maintenance forces in the operating field, a large amount of research and development work was required to overcome electrical losses in the coils that otherwise would largely, if not wholly, have neutralized the expected benefits from loading. These electrical losses had to be overcome, a step at a time, by patient, exhaustive scientific research. To make the invention practically useful, it was essential to develop coils of an efficiency much greater than any ever before made. Both Pupin and Campbell had done their experimenting with air-core coils. On account of crosstalk, coils of the air-core type could not be placed in proximity to each other. They were, therefore, unsuited for use in loading groups of circuits in cables. It became necessary to design iron-core coils using iron of a special kind. This iron was drawn into a wire as fine as a hair. Ten miles or more of it were needed to wind a single core. The entire ten-mile length had to be insulated with a thin lacquer coating to prevent wasteful eddy current losses. Figure 24 shows the type of core and completed coil that came into use in 1904 for loading circuits in cables. On each half of one of these doughnut-shaped, iron-wire cores there were wound many turns of insulated copper wire. One of these latter windings was connected into one wire of the telephone circuit, and

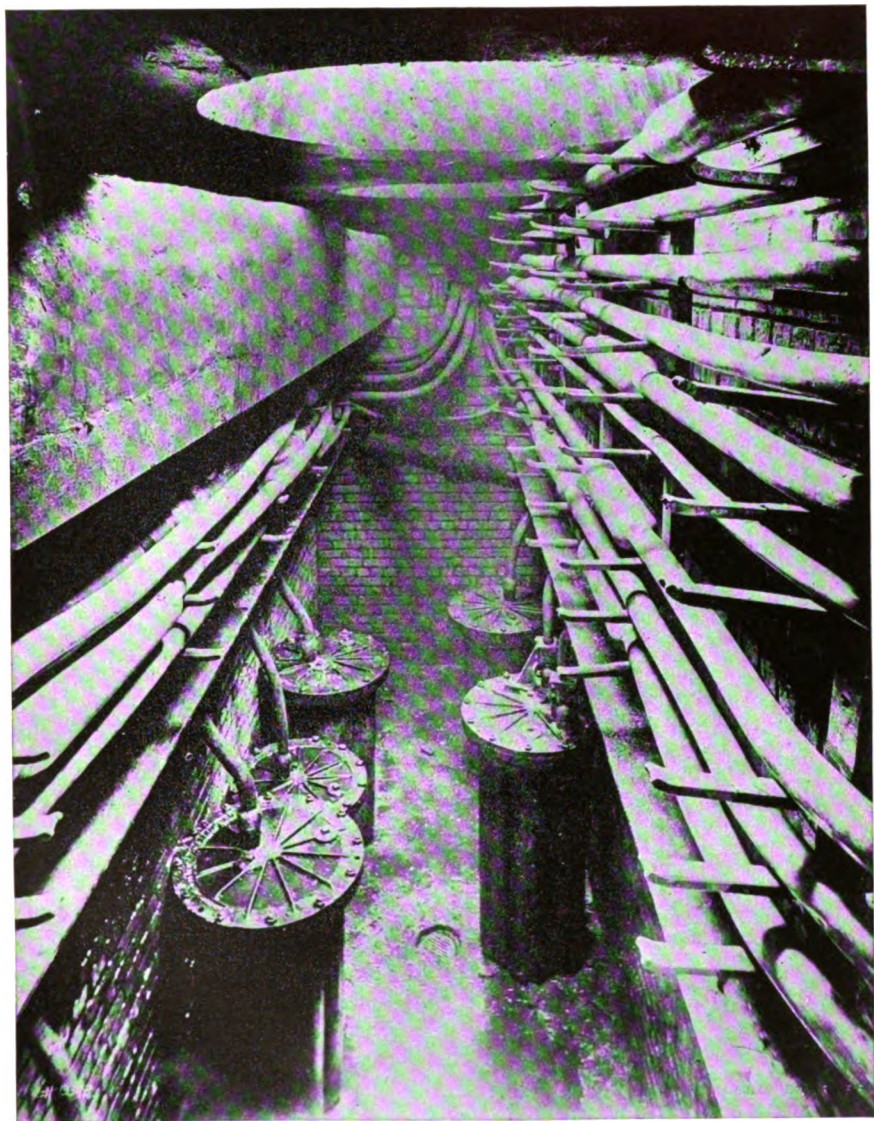


FIG. 26—Loading coil cases in a manhole, showing method of connection to cables.



the winding on the other half of the core was connected into the other wire of the telephone circuit. The coils were spaced along the cable at intervals of something over a mile.

Although this book does not, in general, attempt to deal with improvements of the last twenty-five years, it may prove of interest to make an exception in this chapter and to refer briefly to some of the later improvements in loading coils.

One of the most noteworthy steps was consummated in 1916. It did away with the use of fine iron wire in the core, substituting for it a core built up of a pile of quoit-shaped rings of a new material; and fortunate it was that this development was completed at this time, for the dies consisting of diamonds in which tiny holes were drilled, through which the fine iron wire had been drawn, were produced within the war zone in Western Europe and, as the supply of these essential tools for drawing the core wire had been cut off by military operations, the further production of loading coils was threatened with interruption. Figure 25 shows one of these cores built up of a series of rings.

The rings were made by compressing insulated fine grains of iron. To obtain iron having suitable properties, it was deposited electrolytically on cathode plates suspended in tanks. After being deposited on these plates, it was stripped off, broken into pieces about an inch square, and ground to fine dust in a mill. The individual particles of iron were insulated with an oxide coating and shellac, and then pressed into rings under a pressure of one hundred tons on each square inch of their surface. So fine were these particles of iron that a complete core of seven rings contained about thirty-five billion of them. This development was undertaken primarily to produce loading coils of greater magnetic stability and more uniform impedance than the wire-core coils and, while it saved the day so far as the supply of coils was concerned, it also resulted in better and less costly coils.

By the year 1924, improvements having been made in the structure of fine wire cables which rendered them suitable for loading, a type of loading coil making use of a single ring* for its core was developed, principally for loading interoffice trunk circuits in fine-wire cables. This led to substantial savings in plant costs, not only by extending the field of use of fine-wire cables, but also by further savings in the cost of the coils themselves. At the same time, the general

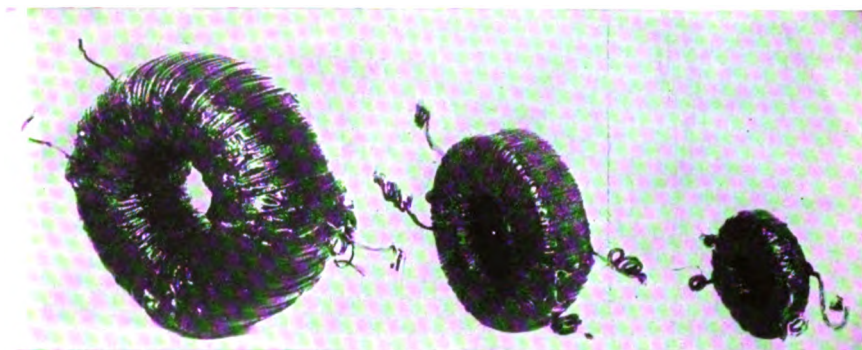
* In 1926 a two-ring core superseded this.

intelligibility of talks over the loaded trunk circuits was appreciably improved, due to the fact that the new loading system permitted the transmission of a wider frequency band, thus reducing line-distortion effects.

As the result of refinements in design and economies in manufacturing methods through the employment of higher speed processes, a further saving in certain types of loading coils was realized in 1926. This improvement was accomplished without any sacrifice in efficiency and, as it permitted a substantial reduction in the size of the coils, it assisted in overcoming a difficulty that was beginning to appear. Loading coils are hermetically sealed in large iron cases, in order to exclude the moisture which would be fatal to their operation. Figure 26 illustrates some of these cases of coils placed in an underground man-hole or vault. It also shows the "stub" or connecting cables by means of which the loading coils in the cases are connected to the main cable which is to be loaded. With the growth of the telephone plant in the larger cities, it was becoming increasingly difficult to find space in the manholes for the cases of loading coils, so that this improvement, by decreasing the size of the coils, allowed more of them to be placed in each case, which was especially welcome.

The next and so far the latest step in the improvement of the loading coils has come about as the direct result of a fundamental scientific discovery—namely, an alloy which has magnetic properties many times greater than those of the best irons and steels hitherto available. It is an alloy of nickel and iron, specially heat treated. It was discovered by G. W. Elmen, in the Bell Telephone Laboratories and it has been given the name of "Permalloy." One of its first important applications was to the continuous loading of transoceanic telegraph cables, where the high magnetic permeability of the substance was a prime requisite. By winding a wire or ribbon of permalloy spirally over the telegraph wire in the submarine cable, the speed of signaling has been so increased that the traffic capacity of a permalloy cable is many times greater than that of submarine telegraph cables constructed in accordance with the previously existing art.

Although permalloy in the form used for telegraph cables was wholly unsuited for the cores of loading coils, its intrinsically low hysteresis (that is, the lagging of magnetization relative to the mag-



1904
Wire-Core Type

1926
2-Ring Iron-Dust
Core Type

1927
Powdered-Permalloy
Core Type

FIG. 27—Three Stages in the Development of Cable Loading Coils. Left: Coil with iron-wire core, overall diameter $4\frac{1}{2}$ inches. Center: Coil with iron-dust core, overall diameter $3\frac{1}{2}$ inches. Right: Coil with powdered-permalloy core, overall diameter $2\frac{1}{8}$ inches.

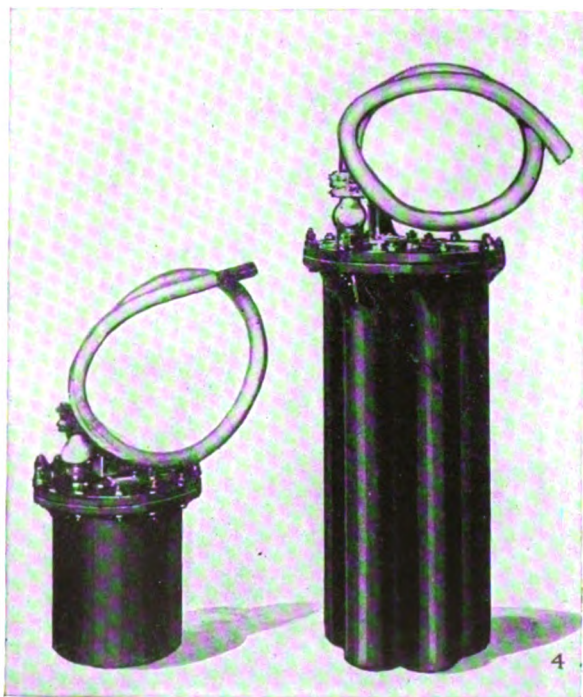


FIG. 28—Reduction in size of case for 200 loading coils due to development of powdered-permalloy core.

netizing force) encouraged the search for some means of utilizing it in loading coil construction.

The technical skill of the laboratory metallurgical experts was focused on the problem of adapting permalloy so that its advantageous properties could be usefully employed in loading coils. The problem was a difficult one, but the solution was found after continuous experimental work extending over several years and calling for the co-ordinated efforts of groups of specialists in the fields of chemical, electrical, and metallurgical science.

Keeping pace with the developments in the laboratories was the work of the manufacturing engineers of the Western Electric Company, who were responsible for initiating plans for producing the new coils in large quantities as soon as the progress of the development work warranted this step. As the result of these cooperative efforts, it has been possible to realize the advantages from this latest step in the evolution of the loading coil at the earliest possible date. Figure 27 shows, on the same scale, at the left, the type of loading coil that represents the state of the art from 1904 to 1916; in the middle, the type of iron-dust coil that immediately preceded the permalloy-core coil; and at the right, the latest coil having the powdered permalloy core for use on interoffice trunk lines. The great reduction in size is apparent, and the very substantial saving in cost can be appreciated when it is realized that loading coils are now being manufactured and installed on local and intercity cables in the plant of the Bell System in the United States at the rate of approximately one million a year. Figure 28 shows, on the same scale, cases equipped with 200 loading coils; the one on the right being a case containing 200 coils of the type immediately preceding the permalloy-dust core coil and the one on the left containing 200 of the coils with the permalloy-dust cores.

The principal fields of application for loading coils are (1) in the longer trunk circuits interconnecting the central offices in the larger cities, and (2) in association with the modern type of telephone repeater for the groups of circuits in the cables that link distant cities together. Due to the application of these devices, an extensive network of interurban cables now ties together the chief cities in the northeastern portion of the United States, and new intercity cables are being added each year. These cables not only provide additional facilities to keep pace with the growing needs of many communities,

but, as far as is humanly possible, they safeguard the telephone service against the menace of storms of extraordinary severity. Figure 29 shows one of these interurban cables supported aerially on short, stocky poles.

In closing this chapter dealing with the invention and application of loading, let us revert briefly to the early work of the British scientist, Heaviside, and the French scientist, Vaschy.

Heaviside published, in the London *Electrician* for June 3, 1887, a paper announcing the proposition that, for distortionless transmission and minimum attenuation, the ratio of resistance to inductance should be equal to the ratio of leakage to capacity. To accomplish this he suggested the use of bimetallic wire, in which iron was to be one of the metals, and also the use of an insulation impregnated with iron dust and therefore magnetic.

Vaschy published a paper in *La Lumière Electrique* for July 2, 1887, also demonstrating beyond doubt that inductance, when uniformly distributed along a telephone line, would improve the transmission performance of the line, decreasing the attenuation and improving the quality of the transmission.

Vaschy, in 1889, proposed to obtain improved transmission "without modifying the state of the line, by introducing at certain distances . . . coils offering sufficient self-induction and insignificant resistance." But Vaschy gave no indication as to the distance apart he would place these coils.²

Heaviside, in a subsequent paper, also mentioned the use of coils, and recommended the construction of a telephone line in which the coils should be spaced one kilometer apart. He further specified the inductance which they should possess and that they should have as little resistance as possible. For these coils he recommended the use of a closed magnetic circuit of finely divided iron.³

To this extent did these two mathematical physicists come near to making the discovery which Pupin subsequently made when he supplied what had hitherto been lacking; that is, the proper rules for the spacing of the coils with reference to the electrical wave lengths.

² Ref. (61).

³ Ref. (62).



FIG. 29.—Toll cable line through open country. Method of supporting and connecting loading coils shown in foreground.

CHAPTER XI

THE BEGINNING OF THE TELEPHONE SWITCHBOARD

BEFORE Bell had invented the telephone and conceived the idea of a telephone "central office where the wires could be connected as desired," there were in operation, in many places, electrical telegraphic signaling systems connecting subscribers with a central station. These systems were used for messenger calls, fire and police calls, and similar purposes; that is, for the one-way transmission of telegraphic signals to a central point, where they were recorded in order that they might receive the necessary attention. In a few cases, however, some limited provision had been made, at the central point, for interconnecting telegraph subscribers' lines.

But in New York City, in 1874, William A. Childs had established the Law Telegraph Company for the special purpose of furnishing an interconnecting telegraph service to lawyers by means of lines equipped with telegraph instruments at the lawyers' offices and terminated at a central telegraph office for switching purposes. In that system the number desired by a calling subscriber was signaled by him to the central office by means of taps on an electric bell associated with his line. The central-office attendant, upon learning in this way the number of the line with which a connection was desired, connected the two lines together and disconnected them, when signaled by taps on the bells to take down the connection. The apparatus was crude and the service was slow. Rapid and frequent interconnection of the lines was not a prime requisite.

The story of the first provisions made for interconnecting telephone lines was told by Mr. T. D. Lockwood, before a meeting of telephone men, in the following words:

"In 1877 Mr. E. T. Holmes was carrying on an electrical burglar-alarm business at 342 Washington Street, Boston. He had a number of lines already in existence. Telephones were placed at the offices of a number of the subscribers to this system, and by means of a switchboard, purchased for the purpose by

Mr. Holmes, the lines were (connected) up on the 17th day of May, 1877, and thereafter repeatedly placed in intercommunication.”¹

Figure 30 shows the arrangement that was employed. At the burglar-alarm office each subscriber's wire was connected to a small metal block. These blocks were so placed in proximity to each other that metal plugs could be employed in connecting them together. Continuing the quotation:

“calling was done in both directions by means of the burglar-alarm apparatus. This was later discontinued, because the subscribers were not willing to pay for the luxury as the telephone was then considered.

“The next historical telephone exchange was located in the drug store of Isaac C. Smith, at Hartford, who leased a lot of telephones from the New England Telephone Company and constructed a series of lines from a number of doctors' offices and livery stables to his store, furnished the telephones to the said doctors and stablemen, established a home-made switch and a call bell in his store, and was in the habit of connecting the doctors' lines to one another and to the stables, as they might be called for. This exchange was brought into some local prominence, as a railroad accident occurred one night during its existence at Tariffville, on the Connecticut Western Railroad, and the news coming to Hartford, the doctors were collected to go out on a special train by means of their telephones, upon call from Mr. Smith, much quicker than they could have been otherwise.”²

Smith's “central office” was essentially a point where were terminated certain private lines serving a particular class of patrons. The installation consisted at first (in 1877) of a single line to which various physicians and livery stables were connected for their mutual convenience. Subsequently, other lines were added, but it was a neighborhood system and not a commercial telephone exchange.

In 1874 there existed in Bridgeport, Connecticut, a neighborhood telegraph association, operated on a mutual expense-sharing basis, and known as the Bridgeport Social Telegraph Association. It was promoted and managed by Thomas B. Doolittle, who, it will be re-

¹ Ref. (42), p. 52.

² Ref. (42), p. 52.

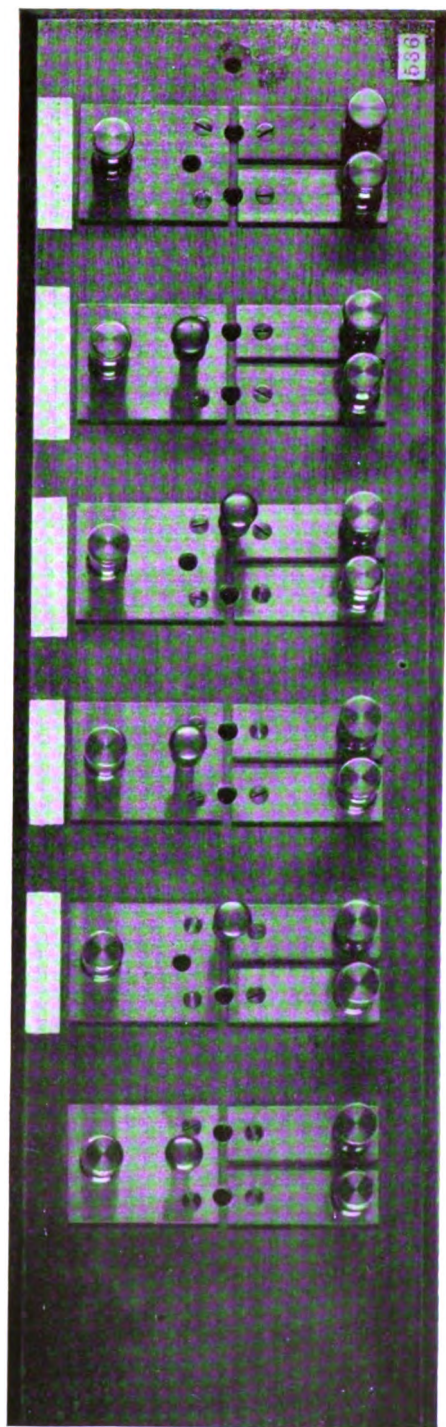


FIG. 30—Reproduction of plug and block apparatus designed and used in Boston in 1877 by E. T. Holmes for interconnecting telephones by utilizing, in the daytime, wires that were employed for a burglar-alarm system at night.

membered, was the first to suggest and urge the use of hard-drawn copper wire for telephone lines. The members of this association at first used telegraph instruments as their means of communication. The several telegraph lines terminated in the office of the Atlantic and Pacific Telegraph Company in Bridgeport, and the local manager of that company taught the members how to send and receive telegraph messages. In 1877 several lines of the Bridgeport Social Telegraph Association were equipped with telephone instruments and, in that year, Doolittle had made a six-point, crossbar switchboard, in which simple switches were substituted for the usual plugs of the telegraph type, to facilitate the making of connections for telephone purposes.

At that time, however, the enterprise was not a commercial telephone exchange in the commonly accepted meaning.

The first city in the world to have a commercial telephone exchange was New Haven, Connecticut. This first commercial telephone switchboard was placed in service on January 28, 1878. It provided for eight lines, on which twenty-one telephones were served. Figure 31 is a model of this primitive switchboard. For the benefit of anyone interested in tracing in detail the method of operating it, a full description, with a circuit drawing, is given in Note A at the end of this chapter.

The first switchboard of the Bridgeport Social Telegraph Association was succeeded by one which Doolittle planned and had constructed, in July, 1878, by Charles Williams, Jr., of Court Street, Boston.^a Mr. Williams has stated that this twenty-line switchboard was "the first switchboard completely equipped with signaling apparatus ever made at my establishment." It was at this time that the Bridgeport enterprise became a commercial exchange.

In the same year, 1878, the American District Telegraph Company opened a telephone exchange at 118 La Salle Street, Chicago. It was known as the Edison exchange because its stations were equipped for telephone service with Edison transmitters, the patents for which were, at that time, owned by the Western Union Telegraph Company.

This exchange is of historical importance because the growth which took place in it gave rise to the original idea of the multiple switchboard. Its method of operation was so peculiar as to warrant explanation.

The stations which it served were originally and primarily district

^a Ref. (63).

call-box stations, designed to send telegraphic signals for messengers, police, etc., to the central office where they were recorded in order to receive the attention of the attendant. Several of these call-box stations were grouped on a single line. When the addition of telephone service was offered to these stations, the plan adopted was to install the telephone instruments at the station and to connect them with the central office switchboard by a separate grounded wire for each.

No provision was made to signal the central office over the telephone wire when it was desired to originate a call. Instead, the call-boxes were remodeled so that they could be used for this purpose by adding to them two extra telegraphic signals—one to indicate at the central office the desire to have a connection established; the other to have it taken down.

At the switchboard each telephone wire was terminated in a metallic socket. Each of these sockets was an ordinary wood screw with a small hole drilled lengthwise in its head. When the sockets were screwed into the face of the switchboard, the telephone wire was laid alongside the screw and contact was made by the pressure of the screw threads against the wire. As said above, there was no signaling apparatus associated with these line-terminal sockets.

The calls came in over the call registers and were received by an attendant or clerk, who wrote a ticket giving the name of the party who was calling and passed it to the operator at the telephone switchboard.

The telephone operator then connected his own telephone, by means of a flexible conductor provided at the end with a metallic pin adapted to fit into the holes in the screw sockets, with the line of the calling party, who, after sending the signal by means of his call-box, had meanwhile stationed himself at his telephone in readiness to give the name of the party, with whom he desired to talk, to the operator as soon as the latter had connected his instrument to the calling party's telephone line. The operator completed the desired connection by means of a flexible connecting wire equipped at both ends with pins for connection to the sockets. When the conversation ended, each subscriber was supposed to signal the fact by means of the arrangement provided in his call-box and, when the signal was received by the register clerk, he instructed the operator to take down the connection.

At that time C. E. Scribner was an electrical expert in the employ

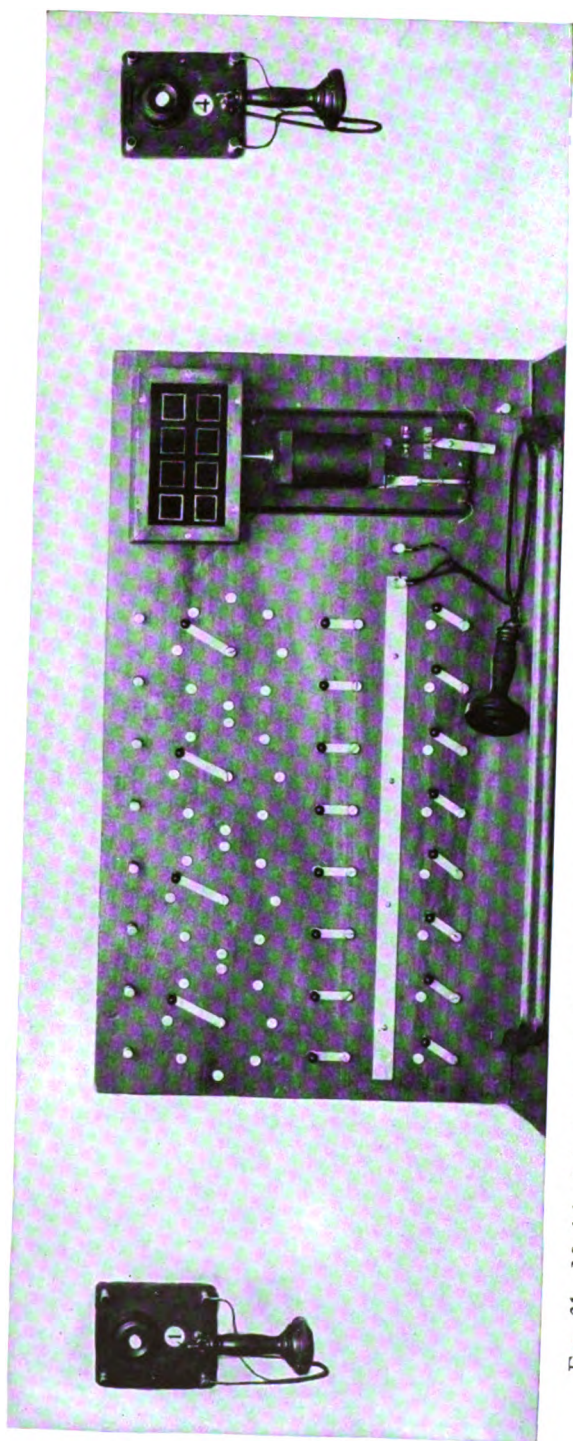


FIG. 31—Model of first commercial telephone switchboard, installed at New Haven, Connecticut, in 1878. The substitution sets at either side of the switchboard are provided with push buttons for signaling and “butter-stamp” telephones that served for talking, listening and receiving signals. The arrangement of the switches shows the switchboard in readiness to receive a call. A full description of this switchboard, with a circuit drawing, is given in Note A at the end of this chapter.

of the Western Electric Manufacturing Company, at Chicago. Subsequently he became chief engineer of the Western Electric Company. In an address to the Telephone Pioneers of America, in 1916, he spoke of this early switchboard as follows:

"The original switchboard was located in the public A. D. T. office . . ."

"After about 50 or 100 telephone lines had been established, it was found that the public office was too crowded and unsuitable for this telephone exchange, so the apparatus was moved into a small room back of the public district office, to which the register clerks in the front office sent tickets for 'telephone use' and 'telephone through' by messenger.

"The lines increased until this small room was found inadequate and the telephone apparatus was moved into a larger back room, and special call registers provided for the telephone subscribers. In this room the number of lines multiplied so rapidly that Mr. Firman* was obliged to put on assistant operators and switchmen, and finally to provide extra switchboards for the accommodation of the additional lines. This created another difficulty in the necessity of connecting between switchboards when a subscriber on one switchboard wanted a subscriber on another switchboard. As the number of subscribers further increased and connections on the switchboards became more numerous and confusing, it was evident that the switching facilities were inadequate, and that a radically improved system would be necessary in the near future."

It has been worth while to describe this exchange at some length in order that the conditions which led to the idea of the multiple system may be understood.

Quoting further from Scribner's paper:

"There were in the Edison exchange many lines which were outside of the range of call-box service given by the American District Company; and these lines were specially treated by the provision of line signals operated by relays. Rows of terminals, normally connected by flexible cords, were provided for the connection and disconnection of the line signals, and many motions

* Leroy B. Firman, the General Manager of the American District Telegraph Company at Chicago.

were necessary for an operator to effect a connection between two such subscribers."

Scribner's first telephone invention*—he subsequently made more than five hundred others—was a switch to facilitate connections between subscribers of this class. This switch was the progenitor of the modern "jack," both in its functioning and in its name. It was called a "jack-knife" switch on account of its resemblance to the pocket clasp-knife which bears that name. Figure 32 is a photograph of one of these switches and the plug used with it.

The jack-knife switch consisted of a metal plate about two inches long, one-half inch wide, and one-quarter inch thick, screwed flat against the face of the switchboard. Scribner himself described it as follows:

"A movable member, hinged at one end and controlled by a spring, resembled the blade of a jack-knife. Mounted on the frame, but insulated therefrom, was a contact point against which the end of the movable member normally rested and made electrical contact. Two plug holes were provided . . . so arranged that the movable member or 'blade' partly closed these holes, whereby the insertion of a plug would force the blade slightly out of position, and open the normal contact.

"In this circuit, the telephone line wire was connected to the metal plate, and from the normal contact of the switch a wire was extended to the line relay and thence to ground, thus doing away with the relay cord. A contact of the line relay closed a local circuit through an annunciator signal and battery. The second plug hole in the frame member of the jack-knife switch permitted connections to be made between jacks while the operator's plug remained in the first hole."

This invention was adopted by Firman for use in his exchange for the lines not having call-box service, and it was employed in the Western Electric Manufacturing Company's "Universal Switch," which was placed on the market in 1879. Figure 33 shows a single section of this "Universal Switch." At the top were twenty-five annunciators with drop shutters. Directly beneath these were twenty-five jack-

* U. S. Patent No. 293,198, application filed August 23, 1879; issued February 5, 1884.



FIG. 32—Scribner's "jack-knife" switch and the plug used with it.

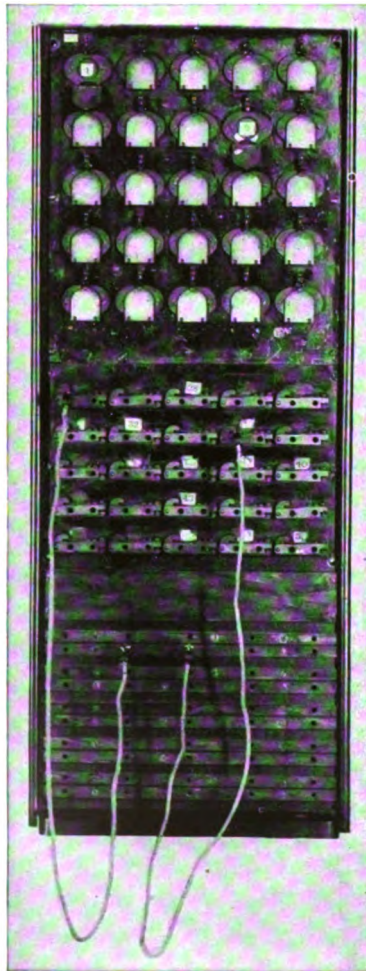


FIG. 33—The "Universal" Switchboard of 1879. See Note B at the end of this chapter for a circuit drawing of this switchboard and a description of its method of operation.

knife switches. Below these was a broad calling-plate, under which were ten horizontal metal straps used for interconnecting the lines. The picture shows two subscribers' lines connected together by means of two cords, the lower ends of which are connected to the same metal strap and the upper ends to the jack-knife switches of the individual lines. Those who may wish to familiarize themselves further with the operation of this switchboard will find a description of its operation in Note B at the end of this chapter.

At this point a digression will be made to describe the switchboard of the Gold and Stock Company, installed in 1879 in New York City, and patterned closely after the "Universal Switch." Figure 34 shows a general view of the "Gold and Stock" switchboard. Metal bars which ran the length of the room were used instead of metal straps for interconnecting the lines, and the clearing-out drops were located in a special position. Figure 35 shows one operator's position, or portion, of this switchboard and the operator with his hand telephone set. One of his telephone set cords is plugged into a jack-knife switch and the other is connected to the ground plate. The method of operation was almost identical with that of the "Universal Switch," except that, as this was a large switchboard, the desired subscriber's line was likely to be terminated in a jack considerably distant from the operator who answered the call. He, therefore, connected the calling subscriber's line to an idle bar, and turned the bar somewhat to indicate to the other operators that it was in use, and called out to the operator at the distant position to connect the desired subscriber to the same bar. This practice, of course, resulted in much clamor and confusion.

Figure 36 shows the clearing-out position of this switchboard with the operator in charge. There was one clearing-out signal* for each metal bar. When a drop fell, denoting the termination of a conversation, the clearing-out position operator called to the line operators the number of the horizontal bar from which the connections were to be taken down, thus contributing his share to the general vociferation. The operators' handsets of 1879 were of low power and capable only of talking over short distances. When more efficient battery transmitters were designed, their use was abandoned.

The reader will already have noticed that the operators of that time were boys or young men. Mr. Eckert, of Cincinnati, speaking in 1881, said:

* U. S. Patent No. 303,714, H. H. Eldred; application filed June 9, 1880.

"I should explain about the number of operators, that sixty-six of them are ladies. . . . I would like to say right here, I have been asked by Mr. Sabin what our experience has been with young ladies' help; the service is very much superior to that of boys and men. They are steadier, do not drink beer, and are always on hand." ⁴

We now resume the thread of the story of the beginning of the multiple switchboard. Said Scribner:

"When, in the fall of 1878, the number of telephone lines and calls in the Edison exchange had increased to such an extent that Mr. Firman realized that the switching facilities were inadequate and a radically improved system would become necessary, he gave this situation close personal attention, and his study of the matter resulted in the initial and basic idea of the telephone multiple switchboard.

"His plan was to provide duplicate switchboards, on each of which all of the telephone lines would appear so that any two lines might be connected together on either of the boards. This was the broad invention of the multiple switchboard, and Mr. Firman is entitled to full credit for pointing out the way to unlimited expansion of the telephone exchange systems." ⁵

Firman sought and obtained the cooperation of the Western Electric Manufacturing Company in carrying out his idea. Early in 1879 he installed two duplicate switchboards, each having means whereby connection could be established with any of the entire number of lines terminating at the exchange—about one thousand in all. With this arrangement it obviously became necessary for the operator at one of the switchboards to know whether a line with which connection was desired was already in use as a result of a connection established by the operator at the other switchboard.

Firman devised an ingenious method for accomplishing this by means of an auxiliary panel, placed where the operators could easily see it. This he called a "target board" because it was equipped with hooks on which removable targets or tags could be hung. The hooks on the target board were arranged in like numerical order to the line terminals on the switchboards.

⁴ Ref. (36), p. 112.

⁵ Ref. (64).

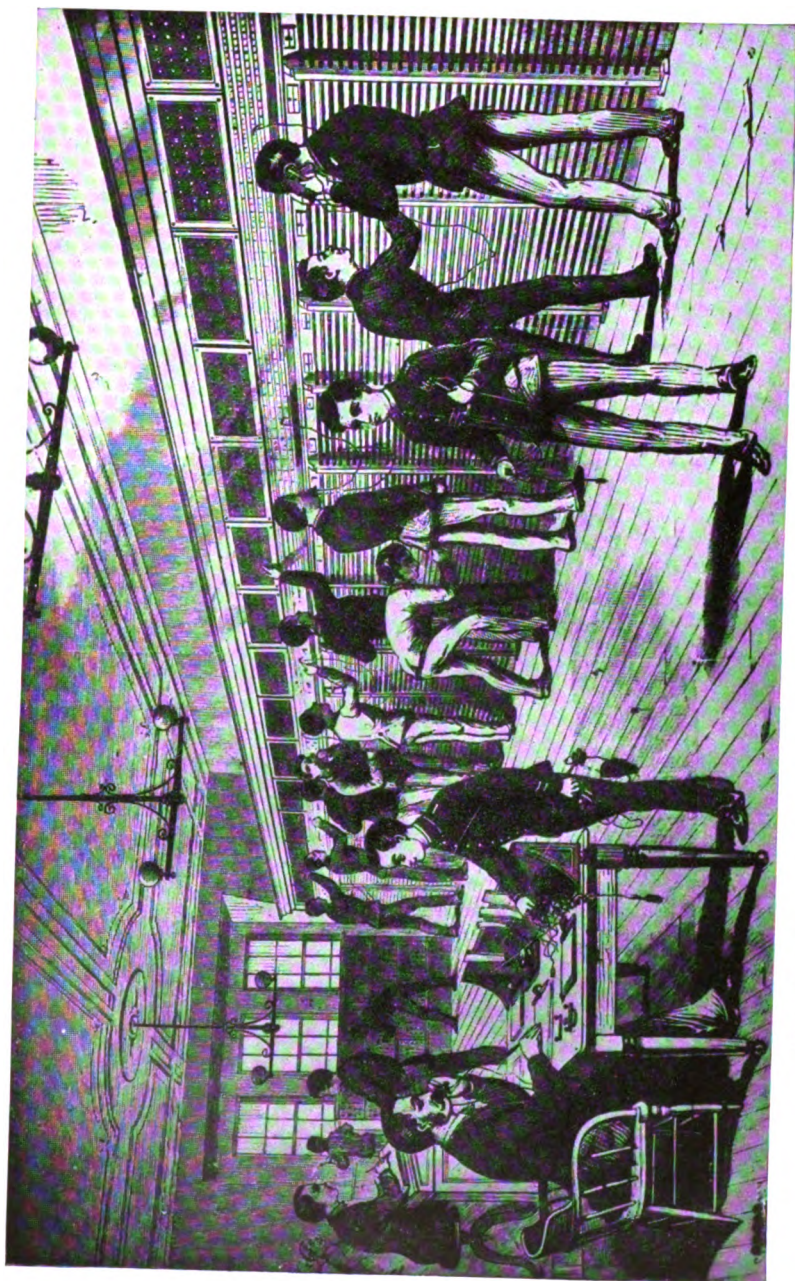


FIG. 34.—General view of the "Go'd and Stock" switchboard of 1879.

The target board was in charge of a special attendant, known as the "target operator." Whenever one of the switchboard operators connected two lines together, the fact was reported to the "target operator" who hung tags on the hooks corresponding to the lines which had been interconnected. Thus, by looking at the "target board," an operator at the switchboard could determine at a glance whether a line, with which connection was desired, was already "busy" or not. Likewise, word was passed to the "target" attendant to remove the tags as soon as the lines were disconnected.

It apparently did not occur to Firman, at the time, that in his multiple idea he had made an invention.

Scribner is authority for the statement :

"At a later date, Mr. E. M. Barton, I believe, called attention to the fact that Mr. Firman had made an important invention and suggested that the latter take out a patent to protect it, and offered to purchase such a patent when secured. Mr. Firman, therefore, filed his application on January 7, 1881, and a patent (No. 252,576) was issued on January 17, 1882, covering the broad switching principle of the multiple switchboard and the same was sold to the Western Electric Company."

Firman's invention provided only for telephone lines operated in association with call-boxes, as already described. Its early development, at the hands of the Western Electric Company, progressed rapidly through several stages.

Scribner conceived the idea of providing, for each of the subscribers not equipped with call-boxes, "a series jack-knife switch on each of the multiple switchboards. Their lines were wired as usual to the body of the first jack-knife switch, the normal contact of that switch being wired to the body of the switch on the next board and so on to the last normal contact, which was wired to ground through a line relay, having an annunciator signal and battery wired in circuit with its local contact."⁶

Scribner next invented a pneumatically controlled system of visible signals whereby the insertion of a plug into the jack-knife switch of a line would automatically indicate, by the operation of a signal at each multiple section of the switchboard, the fact that the line, with which the signal was associated, was busy.

⁶ Ref. (64).

In October, 1879, Charles H. Wilson and Clark C. Haskins invented * a "try" circuit with which the switchboard operator could make a test by connecting a "try" plug, leading from a battery through a signaling instrument, to an extra test, or "try," contact, placed adjacent to each jack-knife switch. If the signaling instrument responded to this test, the operator knew that no plug was inserted in any of the jack-knife switches of the line being tested. Said Scribner:

"This was the first invention by which an operator could electrically test a line to determine whether it was busy and it was one of the fundamental steps in the evolution of the multiple system." †

A few days after the Wilson and Haskins invention had been made, Scribner improved it by associating, with each line of series-multiple jacks through the switchboard, a second line of switches for testing purposes only. By providing a test plug arranged for the application of a calling battery, Scribner enabled the operator to plug into a test switch, apply the busy test there, and if the line were found not to be "busy," to ring the desired party and to talk with him, using the regular line switches later to connect the parties together.

In October, 1879, Milo G. Kellogg invented ‡ a multiple testing system, which added extra contact springs to each jack-knife switch so that the blade of the latter, when a plug was inserted, would press against an insulated pin, forcing the springs together. This was the first plan to use an individual contact of a busy test circuit, insulated from the line circuit, adjacent to each jack on the multiple switchboard.

Scribner almost immediately made further improvements by substituting strap keys for his line of test switches, so that an operator, by depressing a "try" key, could test a line and, if it were not busy, send the ringing impulse to the desired party's telephone, and quickly plug into the line switch in order to hold the line from other operators.

J. C. Warner invented § a series spring-jack, having a stout spring for the moving contact instead of a hinged blade. This spring-jack had a mounting plate whereby it was held in place on the face of the switchboard by two screws. The operating parts of the Warner jack

* U. S. Patent No. 266,287, issued October 24, 1882.

† Ref. (64).

‡ U. S. Patent No. 308,315, issued November 18, 1884.

§ U. S. Patent No. 281,741, July 24, 1883; "Spring Jack Switch for Telephone Exchanges."

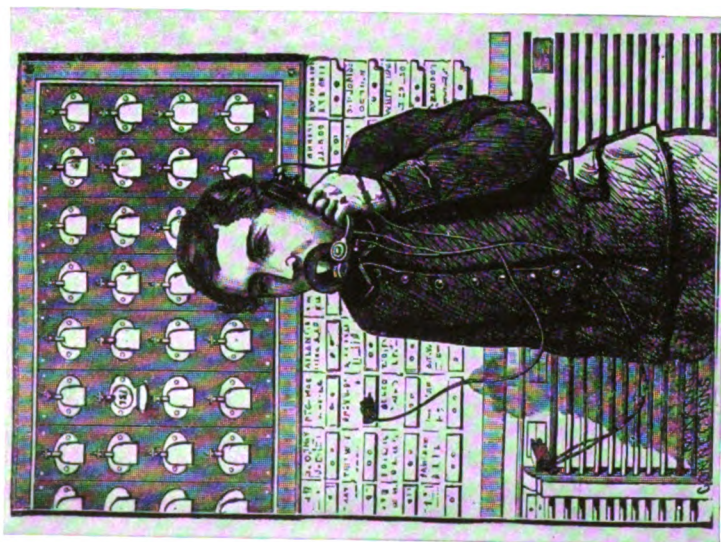


FIG. 35

FIG. 35—An operator's position of the "Gold and Stock" switchboard.

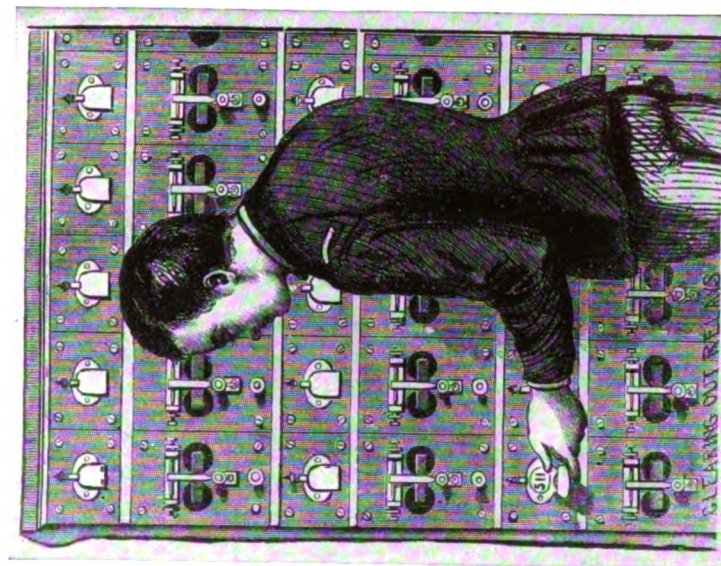


FIG. 36

FIG. 36—The "clearing-out" position of the "Gold and Stock" switchboard.

extended perpendicularly through a hole in the switchboard and the wires were connected to it at the back of the board.

E. P. Warner, at about this time, invented * a telephone annunciator drop which, said Scribner :

“consisted of an electromagnet, mounted horizontally from the back of the switchboard, with its pole-pieces protruding through the face of the board. A sheet-iron drop shutter was pivoted on the face of the board with its pivots slightly above these pole-pieces. The shutter normally laid back against the face of the board at a slight angle beyond the perpendicular. The tail of this shutter, below the pivots, swung in front of the curved pole-pieces of the electromagnet and a very slight current through this electromagnet would over-balance the shutter and cause it to fall and indicate.”

So sensitively were these shutters poised, that the windows of the exchange had to be kept closed, and the operators forbidden to fan themselves in hot weather, lest the air currents should bring down the shutters in large numbers.

In 1880 the Western Electric Manufacturing Company brought out its so-called “Standard” switchboard (Fig 37), embodying many new improvements, with a convenient arrangement of parts. It had a key shelf and flexible connecting cords arranged in pairs with cord weights to restore the cords to their position of rest. With each pair of cords was associated a disconnect signal or drop, and ringing keys were provided. Note C at the end of this chapter contains a detailed description of this “Standard” switchboard and its method of operation.

At about this time a multiple switchboard, large for its era and the only one of its kind installed, was built for use in Indianapolis. It contained the Scribner series multiple key “try” circuits; the J. C. Warner spring-jack; and the E. P. Warner drop. In it, each line passed through each of the multiple boards in series, back through the test keys, and terminated on a separate answering board. The connections were ordered up by the answering operators sending tickets to the switchmen at the multiple boards, who made the busy tests and put up the connections.

Subsequent to the installation of the Indianapolis switchboard,

* U. S. Patent No. 232,093, September 7, 1880; “Electrical Annunciator.”

Scribner made an important improvement * in the "busy test," which he described as follows:

"Instead of using an electric test bell to indicate to the operators when lines were busy, I arranged for a click to occur in the operator's receiver whenever she listened on a pair of cords and tapped the calling plug on to the thimble of the spring-jack of a busy line. I provided a circuit in which these thimbles were connected together as a busy test feature, and the thimbles of a line would be crossed with the line itself when a plug was inserted in any spring-jack of that line. These were single conductor plugs and cords. Each telephone line was grounded at the subscriber's end, and a battery circuit would be closed through the operator's receiver and a click heard when she tapped the plug into the thimble of a busy line."⁸

F. Shaw invented † the idea of a head-band receiver to be worn continuously by the operators, and Wilton L. Richards invented ‡ a light form of telephone receiver to be attached to the head band. These appliances made it convenient for the operators to make these tests, which were practically automatic, as the click test was incidental to the insertion of the plug in the jack. It served to increase the speed and reliability of the service.

About 1885 Carty invented an improved form of busy test, which avoided the connection between a line in use and its test circuit by providing a local circuit, in the switchboard, for the busy test. This he accomplished by means of an extra conductor through the cord and in the plug. Connection to any line, when a plug was inserted in a spring-jack, was established through the tip of the plug to the spring of the jack. The busy test was placed on the test wire by a metallic sleeve on the plug, insulated from the rest of the plug structure, through the extra conductor of the cord and the test battery to ground. This became an important feature which survived in modern manually operated switchboards.

Quoting further from Scribner:

"The next step in the developments which led up to the modern multiple switchboard, was the placing of the line drops in panels

* U. S. Patent No. 330,060, issued November 10, 1885.

⁸ Ref. (64).

† U. S. Patent No. 268,554, issued December 5, 1882.

‡ U. S. Patent No. 304,667, issued September 2, 1884.

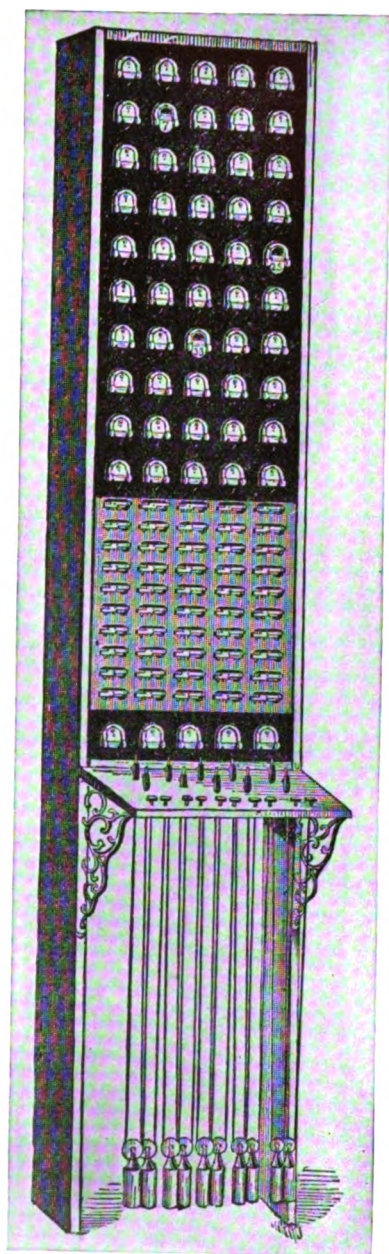


FIG. 37—The “Standard” Switchboard of 1880. See Note C at the end of this chapter for a circuit drawing of this switchboard and a description of its method of operation.

at the sides of the multiple switchboards, such a number of drops assigned to each board as the operator or operators on that board could handle. In this arrangement keyboard shelves were provided, cords and plugs with pulley-weights were furnished in pairs, and ringing and listening keys provided; the result being that an operator could answer, test, connect, and disconnect.

"This brought the operations on each call entirely within the work of a single operator and wonderfully improved and quickened the service. At last the multiple board had been developed into a unit type in which each operator was situated about as favorably for giving service as in the case of an operator in a small exchange with a few lines."

Up to this time, the sections of a multiple board had been located without particular reference to each other, wherever it was convenient to place them in the operating room. Said Scribner:

"It was inconvenient to work two or three operators on a section because only the one at the middle of the section could conveniently reach all of the lines in the multiple. I proposed that all of the sections of multiple spring-jacks be placed in a continuous line in close formation, one section following the other, thus providing an uninterrupted bank of jacks in which all the lines of the exchange were repeated in each section, and any operator could reach all the lines as easily as the operator in the middle of a section. To do this, I moved the answering signals from the sides of the unit multiple sections and placed them along the top of the contiguous multiple switchboard. The drops were to be located above the multiple jacks together with the connecting cords and plugs. The ringing and listening keys remained on the keyboard which continued throughout the length of the multiple board with operators at convenient intervals."⁹

An important improvement,* due to J. A. Seely, was the provision of a separate answering jack for each line, and the close association of each answering jack with its corresponding annunciator. These were located in front of each operator and below the multiple jacks. This invention relieved the congestion of cords in front of the multiple jacks and added to the convenience of operating, as it had previously

⁹ Ref. (64).

* U. S. Patent No. 330,067, application filed March 28, 1885.

been inconvenient for the operators to answer the subscribers whose multiple jacks were situated high in the multiple jack panel.

On January 31, 1887, Mr. H. B. Thayer (who subsequently became president of the American Telephone and Telegraph Company) filed a patent application * for an important improvement in spring-jacks arranged in strips. He placed the jack-springs in layers or banks, with strips of hard rubber interposed between the different layers in order to insulate the springs of each strip. He also mounted all the springs on one side of the insulating strip. This permitted strips of jacks to be built up, one upon another, without danger of any of the springs becoming accidentally "crossed." It also accomplished an important saving in space, thus permitting an increased number of lines to be placed within the reach of an operator.

In order to distribute the operating load, so that the answering jacks of a block of abnormally busy lines should not be placed before one operator, Enos M. Barton invented † the intermediate distributing frame, which permitted a systematic distribution of subscribers' lines to be made among the operators, taking into account the number of calls customarily received over each line.

In a large switchboard installed at the Cortlandt exchange in New York City, in 1888 (Fig. 38), a wide keyboard was designed having a depression about six inches deep between the keys at the front half of the keyboard and the plugs at the back of the keyboard. This type of switchboard came to be known, on account of this depression, as the "hog-trough" board. In the trough were located the drops, which were thus within easy reach of the operators, but out of danger of damage from the plugs as the connections were taken down. At about the time of the completion of this switchboard, it was decided to use in it a two-wire metallic circuit, so it was recabled and provided with test circuits that allowed both grounded and metallic circuits to be worked together.

As switchboards with more and more sections of multiple became needed in the larger cities, troubles began to be experienced in increasing number, due to the accumulation of dust in the spring-jacks which, as they were connected in series, caused open circuits in the switchboards. This led Scribner ‡ and his assistants, Steiner and O. A. Bell, **

* U. S. Patent No. 400,969, issued April 9, 1889.

† U. S. Patent No. 431,962, application filed March 8, 1890.

‡ U. S. Patent No. 503,099, August 8, 1893; "Bridged Jacks."

** U. S. Patent No. 563,250, July 7, 1896; "Electrically Restored Drops."

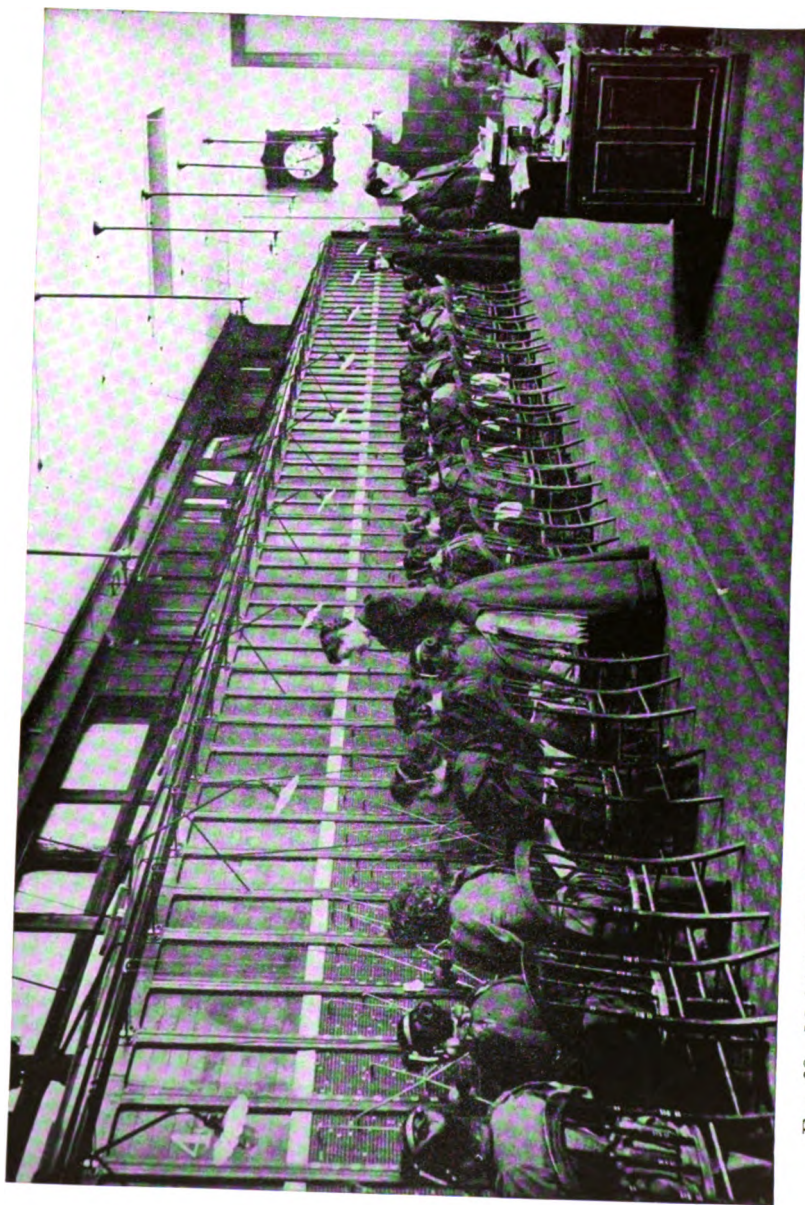


FIG. 38—Multiple Switchboard Installed in the Cortlandt Exchange, New York City, in 1888.

to design a switchboard in which bridged multiple taps were provided from each side of the line to springs in the jacks in the multiple before the operators, and the line signals were wound to a high impedance. By doing this, and adding a locking winding to prevent false operation, the need for disconnecting the line signals from the circuit, when the line was in use, was avoided. A feature which was added at this time was the "self-restoring" line signal or drop. This enabled the annunciator, after being operated, to be restored to its original position automatically upon the insertion of a plug in the answering jack of the calling line. Before this time, the operators had restored the shutters of the line signals to their normal positions by hand. The first switchboard of this type, known as "branch terminal," was installed at Albany, New York, in 1892.

In 1892 W. S. Ford, an engineer of The American Bell Telephone Company and B. A. Lenfest, a draughtsman in the employ of the same company, filed a patent application for a distributing frame embodying structural features that have remained in use for many years. The first claim of their patent * covered "a distributing frame having on one side vertical ledges or supports, and on the opposite side horizontal ledges or supports, and metallic terminals extending along the edges of said ledges or supports."

Reasonable limits for this chapter will not permit the description in detail of many other systems which, for a time, competed with the multiple system but did not survive.

Among these was the Law system (Fig. 39) in which three wires entered each subscriber's station—a line wire, a call wire, and a common return wire. The subscriber's telephone set was provided with a lever. When he desired to originate a call, he pulled down the lever which, by means of the call wire (used in common with as many as fifty other telephones), connected him directly and immediately with an operator's head telephone. He then asked for the desired number, as "34 on 21," and after hearing a tap on his signal bell, which indicated to him that the operator had received his order, he released the lever and waited for his connection to be made. With this system the operator's job was not an enviable one, as, frequently, a number of subscribers on one call wire were clamoring simultaneously for their calls. In this system the operator could not talk to a subscriber.

Another form of switchboard which was used to a considerable

* U. S. Patent No. 507,424, October 24, 1893.

extent before the advent of the multiple board was the Gilliland board (Fig. 40), in which the connections were established by means of movable pegs.

There were other types of switchboards, however, which were available. The National Bell Telephone Company, in 1880, issued a pamphlet entitled "A Description of the Telephone Exchange System, and of the Apparatus Used in Connection Therewith; also, Instructions for Establishing and Operating an Exchange," which read as follows:

"There are several styles of switchboards that may be used, all depending on the same general principles for their operation. They consist essentially of horizontal and vertical bars crossing one another and arranged so that any horizontal bar can be connected to any vertical bar. It is chiefly in the methods of making the connection that the various switches differ. In what is known as the 'plug' switch, the connection is made by inserting a small metal plug at the point where the horizontal and vertical bars cross one another. There are several forms of the 'plug' switch. The 'Jones Lock Switch' is one of the most prominent. In what is known as the 'Slide Central Office Switch,' the connections are made by means of a sliding contact plug, which can be moved on the vertical bars, and, when placed over one of the horizontal bars, springs into firm contact with it."¹⁰

Mention should also be made of the Sabin-Hampton "express system," in vogue for a time on the Pacific Coast. This system employed groups of small switchboards with trunk lines between them, operated by the "order-wire" method. A distinctive feature of this system was the provision of automatic signals so arranged that the removal of the receiver from the switchhook at a subscriber's station automatically operated a line signal at the central office, and the replacement of the receiver on its hook at the end of a conversation automatically displayed a disconnect signal at the central office. Each trunk line, between the various sections of the switchboard, was also provided with an automatic disconnect signal at the incoming end, this signal being operated by the withdrawal of the plug from its jack at the outgoing, or calling, end.

¹⁰ Ref. (67).



FIG. 39

FIG. 39—Switchboard of the Law System.

FIG. 40—Gilliland Switchboard—1879.

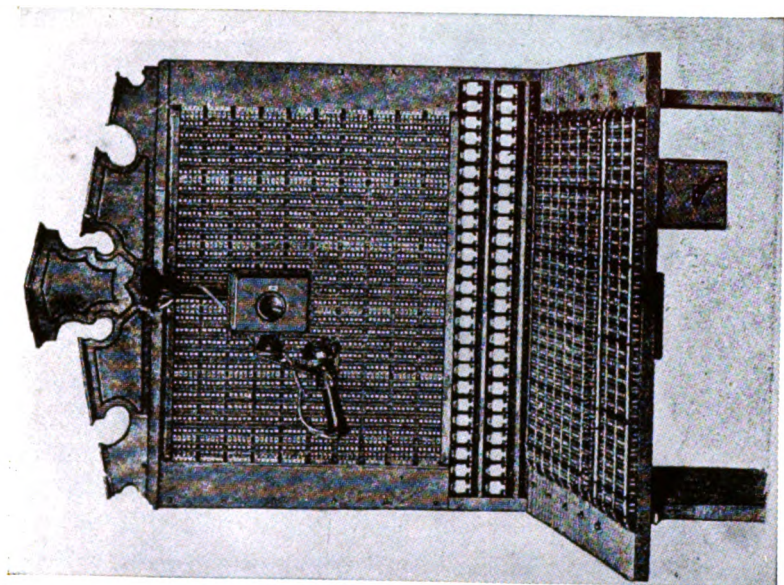


FIG. 40

Richmond, Virginia, central office in 1882.

The Common or Centralized Battery System

The first use of a centralized battery, in lieu of batteries at each subscriber's station, was for signaling purposes only. The term "common battery" has, however, come to be used to designate systems that employ a centralized battery for supplying current to the subscribers' transmitters as well as for signaling.

As early as 1880 Carty, then in Boston, employed a multiple, common battery, metallic-circuit, signaling system, which was used in placing orders for express-wagon service. This system was separate and distinct from the regular subscribers' telephone-exchange service of the Telephone Despatch Company. There were from ten to forty subscribers to this special service on each line, and one centralized battery was associated with the lines for signaling purposes. A user of this service, desiring an express wagon to call at his premises, pushed a button, which caused current from the grounded battery at the central office to flow over the line. This operated an annunciator at the central office, whereupon an attendant answered the call, receiving the necessary information by telephone from the calling party. The attendant wrote this information on a ticket, which was passed to an operator, who telephoned the order to the express company.

Carty was also the first to use common batteries of low internal resistance for telephone transmission, two or more circuits being served from the same battery. This plan was used for supplying the current for central office operators' transmitters."¹¹

In 1886 a patent * was granted to Chichester A. Bell, showing a different method of using a common battery for talking as well as for signaling purposes.

In 1888 Hammond V. Hayes, an electrical engineer employed by The American Bell Telephone Company, and later chief engineer of the American Telephone and Telegraph Company, installed an isolated telephone system in the offices of the former company in Boston, using a central battery of a large number of cells. His U. S. Patent No. 395, 137, December 25, 1888, describes a system of that kind. In 1891 Hayes proposed transferring the induction coil from the subscriber's station to the operator's cord circuit.

At about this time, hopes began to be held that a telephone-exchange system, using a common battery at the central office, might be devised which would operate successfully; and it was apparent that, if this

¹¹ Ref. (68); Ref. (69).

* U. S. Patent No. 346,708, August 3, 1886.

could be accomplished, advantages would be gained from the elimination of the local batteries that hitherto had been required at each subscriber's station to actuate the transmitter.

In the summer of 1892 about eight or ten substations were connected to a section of switchboard placed in the long-distance office in Boston and equipped "with circuits and apparatus so designed and arranged that transmission on the common battery principle was capable of being furnished, and used for some time, several years as I recollect, by several subscribers who had lines equipped with common battery substation apparatus, which lines were terminated at this section of switchboard."¹² The principal early difficulties with the common battery system were with poor speech transmission. To overcome these, new methods and apparatus, including transmitters, had to be developed.

The first commercial installation of this system was at Lexington, Massachusetts.

This was a complete common battery non-multiple exchange, and was installed and put into operation in December, 1893, under the direction of Theodore Spencer, Hayes's assistant. This switchboard employed the repeating coil circuit invented by Hayes (U. S. Patent No. 474,323, filed January 13, 1892, issued May 3, 1892).

A system known as the Hibbard-Sabin was put into operation in Chicago in the fall of 1894. A call-distributing board was provided upon which the line signals and line jacks were placed. The line signals were electric lamps, controlled by relays. The trunk operators were placed at the call-distributing board. They distributed calls to answering operators who were not busy.

The system was in use at the Chicago Oakland office for several years, being ultimately replaced by a multiple common battery relay board. The use of small incandescent lamps for switchboard signals was proposed by J. J. O'Connell, an employee of the Chicago Telephone Company.

In 1895 another modification of the Sabin express system, designed by engineers of The American Bell Telephone Company, was installed at the Market Street office in Philadelphia, where it replaced a Law board. A 16-volt common storage battery operated the line signals and supervisory signals, and supplied the current to the subscribers' transmitters. The line and supervisory signals were of the electro-

¹² Ref. (68), p. 428.

magnetic type. It was a divided board and the calls were trunked between operators.

In June, 1896, there was put in operation at Worcester, Mass., a common battery multiple switchboard, designed by Scribner.

In this switchboard the line and supervisory lamp signals were controlled by the telephone switchhooks at the subscribers' stations through relays energized by a common battery at the central office. When first installed, local batteries were used for talking, although the board was designed so that it could be converted to common battery talking. Condensers were placed in series with the ringers at the subscribers' stations. Repeating coils were used in the operators' cord circuits. This switchboard was designed to be part of a test between the "express" and "multiple" systems, the Western Electric Company agreeing to replace it with a branch terminal board if it were not satisfactory. After this board was in successful operation, traffic observations demonstrated conclusively that multiple switchboards, when equipped with equally good signaling facilities, were preferable to express boards.

At Louisville, Kentucky, there was completed, in 1897, the installation of a multiple switchboard in which was incorporated a common battery at the central office which supplied current to the substation transmitters as well as for signaling purposes, thus doing away with the local transmitter batteries and the hand-operated generators at the subscribers' stations. Lamps on the switchboard, operated by relays, mounted on a relay rack, acted as signals. Each line was provided with a cut-off relay, to disconnect the line from the line relay when a plug was inserted in the answering jack. The common battery was connected to the cord circuits through repeating coils, using the Hayes circuit. A second common battery, of less voltage, supplied the supervisory lamps with current, and a third, of still lower voltage, furnished the current for the line lamps and for the operators' transmitters. About 1898 a single common battery began to be used instead of the three batteries which, up to that time, had been required. Supervisory relays controlling lamp signals were provided in the cord circuits. The Louisville type of switchboard became known as the No. 1 relay board, and was widely used in large exchanges. Its operation is covered in detail in Note D at the end of this chapter.

A bridged impedance type of common battery cord circuit, devised by J. S. Stone and C. E. Scribner (U. S. Patents No. 507,568 and

559,616), has found application in certain types of dial-operated systems.

As early as 1879 patents for an automatic switching system were applied for by Daniel Connolly, T. A. Connolly and T. J. McTighe.* Their system did not, however, become a commercial success. Almon B. Strowger, in 1889, invented † an automatic system which subsequently, at the hands of A. E. Keith and other engineers of the Automatic Electric Company, was developed into a successful system, which came into considerable use under the name of the "step-by-step" system.¹³

Other automatic systems, containing features which have contributed in an important way to the success of modern dial-operated switchboards, were those of J. H. and G. W. Lorimer, on which a patent application was filed in 1900, of Lattig, Goodrum, and Dunham, and that of E. E. Clement, dating from 1906.

This brings the narrative of switchboard developments to a point beyond which it would be inappropriate to go in dealing with the beginning of the art.

NOTE A

NEW HAVEN SWITCHBOARD

Figure 31 is a model of the New Haven switchboard of 1878 and Figure 41 is a circuit diagram showing all of the apparatus and the necessary connections for tracing the progress of a call originated by subscriber A on line 1, for subscriber B on line 4. Referring to Figure 31, at the top of the board were eight binding posts to which the subscribers' lines were individually connected. Below these were the equivalent of two cord circuits, each consisting of a pair of metallic switch arms. Each of these arms was capable of being rotated about an axis so as to connect with any one of eight metal studs, equally spaced on the circumference of a circle. Each pair of switch arms were electrically connected together through the centers about which they could be rotated.

Each of the eight subscribers' lines was connected electrically to one of the metallic studs or buttons belonging to each switch arm. Below these switch arms were eight switches, also capable of rotation and

* U. S. Patent No. 222,458, issued December 9, 1879.

† U. S. Patent No. 447,918, issued March 10, 1891.

¹³ Ref. (70).

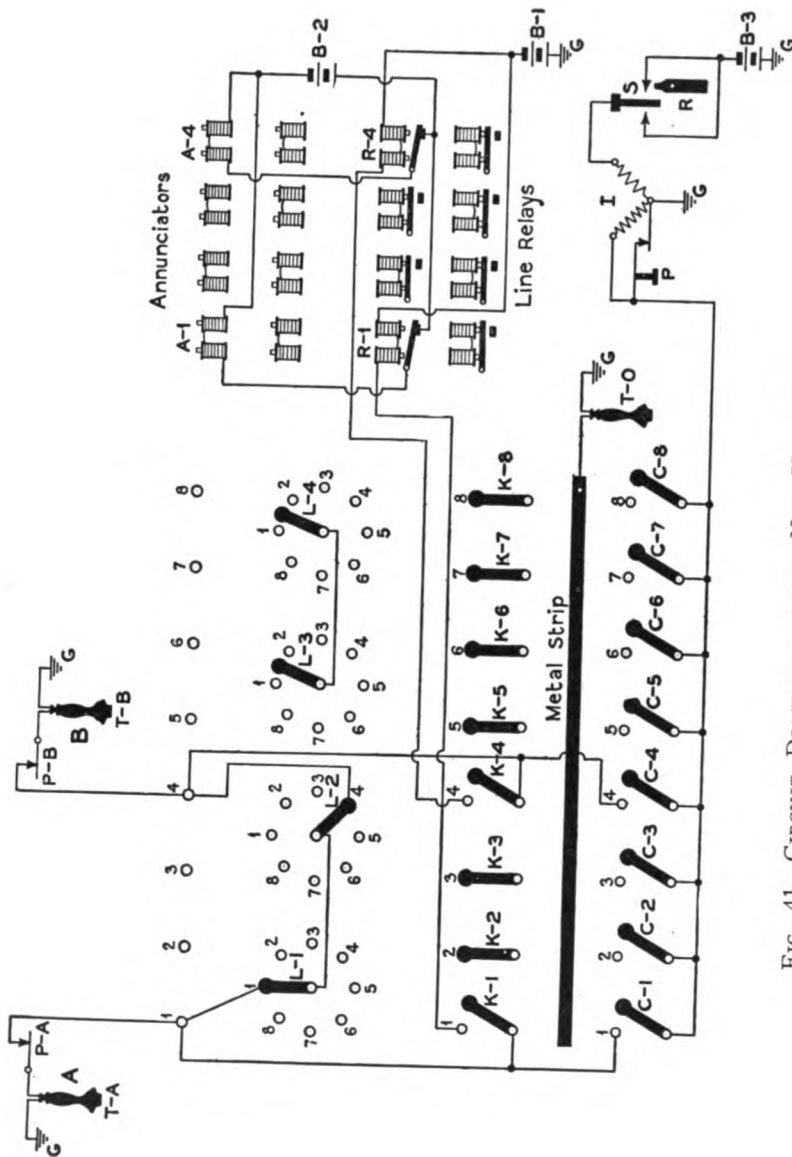


FIG. 41—Circuit Diagram for the New Haven Switchboard

Showing all of the apparatus, and the necessary connections for tracing the progress of a call between subscribers A and B on lines 1 and 4 respectively. Connections show subscribers A and B talking.

each one centrally connected to one of the subscribers' lines. These switches were normally placed in a vertical position where they made contact with a metallic stud. Each stud was connected to battery and ground through a line relay (Fig. 41), which controlled an annunciator operating in a local circuit. The annunciators are shown at the upper right-hand corner of the switchboard (Fig. 31). Each of the eight switches referred to above could be rotated into contact with the continuous horizontal metal strip beneath, to which was connected one terminal of the operator's telephone, the other terminal being connected to earth by means of the binding post shown to the right of the right-hand end of the horizontal strip. The operator's telephone was used both for talking and listening. At the bottom of the board were eight more metallic switches to all of which the signaling mechanism was permanently connected. These switches also were capable of being rotated, each into contact with a metallic stud placed above it. One subscriber's line was connected to each of these studs.

The signaling apparatus, shown beneath the annunciator case (Fig. 31), was Thomas A. Watson's "buzzer." It consisted of a large induction coil, and a flat steel spring, which the operator could cause to oscillate by the hand operation of a lever, thus making and breaking a battery circuit. This action sent a series of electrical impulses over the called line, causing the telephones on that line to "howl" violently.

At each subscriber's station was a single hand telephone, used both for talking and listening, and a push button for operating the central-office annunciator. The system employed grounded lines. A primary battery was used to operate the annunciators and the buzzer.

Referring to Figure 41, when none of the subscribers' lines was in use, the switch arms L-1, L-2, L-3, and L-4 were in the "off" position, as were the signaling switches C-1, C-2, etc. Switches K-1, K-2, etc., however, were all in contact with their metal studs, forming closed circuits from ground, through the subscribers' sets and lines, central-office line relays, battery, and ground.

Method of Operation

Subscriber A, on line 1, desiring to talk to subscriber B, on line 4, depressed his push button P-A, which momentarily opened the circuit through line relay R-1, causing its armature to drop and close a local

circuit through annunciator A-1, which released its shutter, notifying the operator that a subscriber on line 1 desired to originate a call. The operator then moved switch K-1 from its metal stud, opening the line relay circuit for line 1, and rotated it into contact with the metal strip beneath, which connected the operator's telephone, T-O, with the telephone, T-A, of subscriber A, over line 1, now grounded at each end. Upon learning that subscriber A desired to talk with subscriber B, the operator moved switch K-1 from the metal strip to its "off" position, moved switch K-4 from its metal stud to its "off" position, and switch C-4 into contact with its metal stud, thus connecting the signaling apparatus to line 4. To operate the buzzer, the operator moved lever R from side to side, which caused flat steel spring S to oscillate rapidly. The interrupted direct current from battery B-3, passing through the primary winding of induction coil I, caused pulses of induced current to be sent out over the line when plunger P was operated, thus removing the shunt around the secondary winding of induction coil I.

Assuming that subscriber B's signaling code was three, the operator pressed P three times, while operating lever R, which sent three series of impulses over line 4.

The operator then moved switch C-4 to its "off" position, connected switch K-4 to the listening strip, and waited for subscriber B to answer his telephone. When he answered, the operator, after notifying him that subscriber A desired to talk to him, moved switch K-4 to its "off" position and completed the talking circuit for the subscribers by rotating switch arm L-1 into contact with the metal stud for line 1 and switch arm L-2 into contact with the metal stud for line 4.

The operator ascertained when the subscribers had finished talking by connecting either switch K-1 or K-4 to the metal strip at intervals. When, upon listening in this manner, it was found that the conversation was finished, the operator moved switch arms L-1 and L-2 to their "off" positions, and connected switches K-1 and K-4 to their metal studs, thus closing the line relay circuits for lines 1 and 4 and permitting the restoration by hand of the annunciator shutters for those lines.

The method of operation of this switchboard, whereby the line circuits were normally closed through line relay, battery, and ground when not in use, was wasteful of battery current, but it was the only

feasible arrangement at that time in a system in which the subscriber's telephone instrument was employed for receiving the signal from the central office.

NOTE B

WESTERN ELECTRIC MANUFACTURING COMPANY'S "UNIVERSAL SWITCH"

Each subscriber's line and line annunciator terminated in one of the jack-knife switches, which was so constructed that, when there was no plug in either hole, the circuit passed through it; but when a plug was inserted in either hole, the plug was connected into the line and the circuit leading to the annunciator was opened.

The operator was supplied with a telephone set, furnished with two cords, one of which could be attached to a ground plate (shown in Figure 33 at the extreme bottom of the board) and the other plugged into any one of the jack-knife switches. When more than one section of switchboard was used, the sections were lined up side by side and the calling plates and the metal straps of each section were connected together, each metal strap being connected to the corresponding metal strap on each side. Clearing-out drops (not shown in the picture) were also provided for each metal strap for use in notifying the operator when a conversation was finished.

Method of Operation

Referring to the circuit diagram (Fig. 42), subscriber A on line 1 desiring to talk to subscriber B on line 9, operated the call key of his telephone set, which sent a current from ground, through his local battery, through the central-office jack-knife switch, J-1, and annunciator, A-1, to ground, thereby releasing the annunciator shutter. The operator inserted plug P, at the end of cord Q, into one of the holes in J-1, which opened the annunciator circuit and connected his telephone set, T, to A's line, through battery B-1, induction coil I and ground. Upon learning that subscriber A desired to talk with subscriber B, the operator plugged into the other hole of J-1 with one end of connecting cord X₁, plugging the other end into an idle metal strap below. He then withdrew cord Q from jack J-1 and inserted it in one of the holes of jack J-9. He then took up another connecting cord, X₂, plugged one end into the other hole of jack J-9, and signaled subscriber B by tapping with the free end of the cord on the call plate

(beneath the jack-knife switches), which was connected through battery B-2 to ground. Assuming that B's ringing code was three, the operator rang B's bell three times. As soon as B answered, the operator plugged the free end of cord X₂ into the same metal strap to which A was already connected. After informing the subscribers that the connection had been established, the operator removed his telephone set cord Q from jack J-9.

When subscriber A had finished his conversation, he operated his call key again, which sent a current from ground, through his local battery, through the metal strap and clearing-out relay R-1, to ground, which operated R-1 and closed a local circuit through clearing-out annunciator C-1 and battery B-3. This released the shutter of C-1 and notified the operator that the subscribers were through talking,

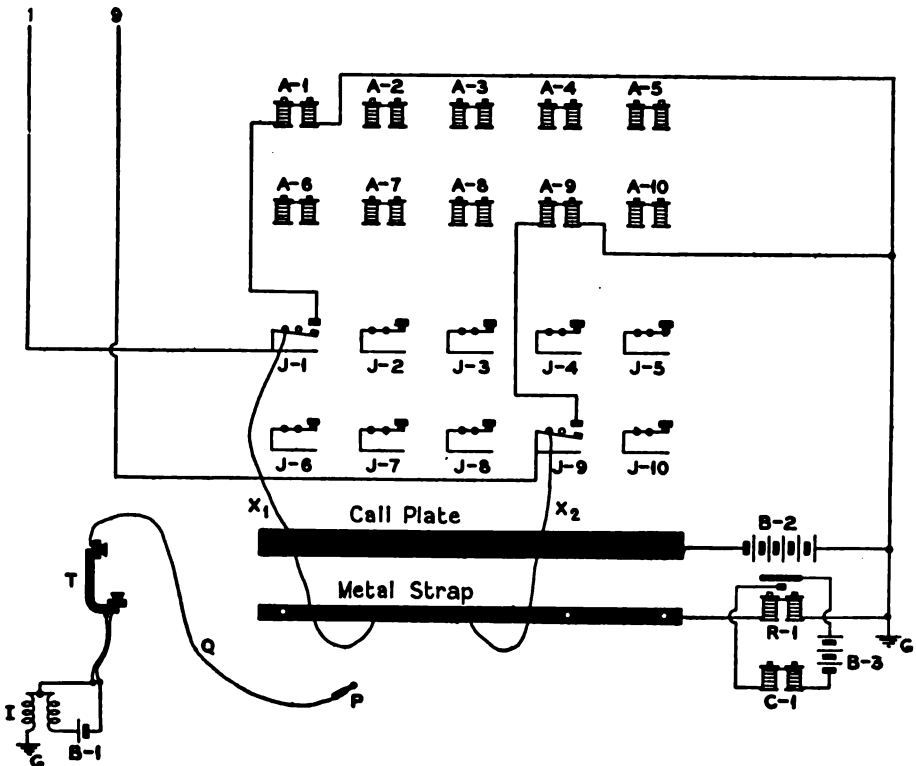


FIG. 42—CIRCUIT DIAGRAM FOR THE "UNIVERSAL" SWITCHBOARD

Showing the necessary connections for tracing the progress of a call between two subscribers on lines 1 and 9. Connections show subscribers talking.

whereupon he took down connecting cords X_1 and X_2 , which closed the annunciator circuits for lines 1 and 9 in readiness for another call. The operator restored the shutters to their normal position by hand. If subscriber A failed to signal upon the termination of the conversation, the operator could "listen in" on the connection by inserting the plug of his telephone set cord in the jack of either A's or B's line.

NOTE C

WESTERN ELECTRIC MANUFACTURING COMPANY'S "STANDARD" SWITCHBOARD

Figure 37 shows a single section of the "Standard" switchboard, with 50 annunciator drops, 50 jack-knife switches, 5 pairs of cords, 5 pairs of listening and ringing keys, and 5 clearing-out annunciators (or drops).

For use in large exchanges where several sections of switchboard were required, transfer jacks were provided along the side of the board (not shown in Fig. 37). The operator's telephone set was connected into the cord circuits, which meant that only one hole was necessary in the jack-knife switches, the same pair of cords being used for listening and interconnecting the subscribers' lines.

Method of Operation

Referring to the circuit diagram (Fig. 43), subscriber A on line 1, desiring to talk to subscriber B on line 5, operated the call key of his telephone set, which sent a current from ground, through his local battery, through the central office jack-knife switch, J-1, and annunciator, A-1, to ground, thereby releasing the annunciator shutter. The operator inserted the plug at the end of cord X_1 in jack J-1, which opened the annunciator circuit and at the same time connected the operator's telephone, T, to A's line, through battery B-1, induction coil I and ground, when listening key K_1 was depressed. Upon learning that subscriber A desired to talk to subscriber B, the operator plugged into jack J-5 with the plug at the end of cord X_2 and, assuming that B's ringing code was three, rang three times on line 5, by depressing ringing key K_2 , which was connected to battery and ground. The operator again depressed listening key K_1 and waited for B's acknowledgment, upon which the operator notified B that he was connected to subscriber A.

When subscriber A had finished his conversation, he operated his call key again, which sent a current from ground, through his local battery, through clearing-out drop C, and over line 5 to ground, releasing the shutter of C and notifying the operator that the subscribers were through talking. The operator then took down the cords, which closed the annunciator circuits for lines 1 and 5 in readiness for another call. If subscriber A failed to signal upon the termination of the conversation, the operator could ascertain if the subscribers were through talking by depressing listening key K_1 .

The annunciator shutters on this board were restored by hand, after they had been operated, as was the case with the previous types of switchboards that have been described.

In cases where magneto-generators were employed at the subscrib-

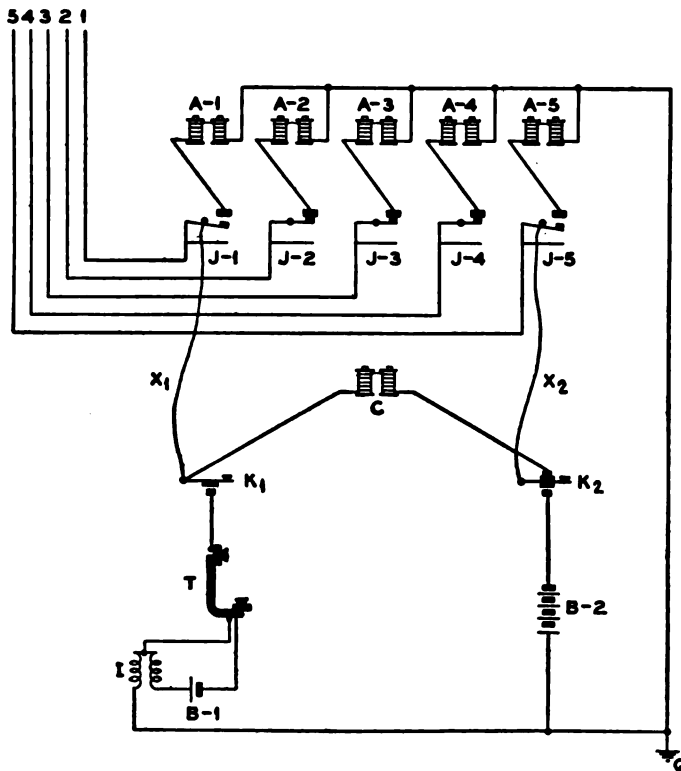


FIG. 43—CIRCUIT DIAGRAM FOR THE "STANDARD" SWITCHBOARD

Showing the necessary connections for tracing the progress of a call between two subscribers on lines 1 and 5. Connections show subscribers talking.

ers' stations, in place of call keys and local batteries, a source of alternating current was necessary at the central office for ringing the polarized substation bells. This was provided by a plus and minus battery and pole changing device at the central office, or by an individual magneto-generator at each operator's position.

NOTE D

METHOD OF OPERATION OF MANUAL COMMON BATTERY SWITCHBOARD

Referring to the circuit diagram (Fig. 44) when subscriber A removes his receiver from the hook, current flows through the circuit from battery B,* operating line relay C, and closing the circuit through line lamp D. The lighting of D in front of the operator notifies her

* The several batteries marked B are actually one common storage battery.

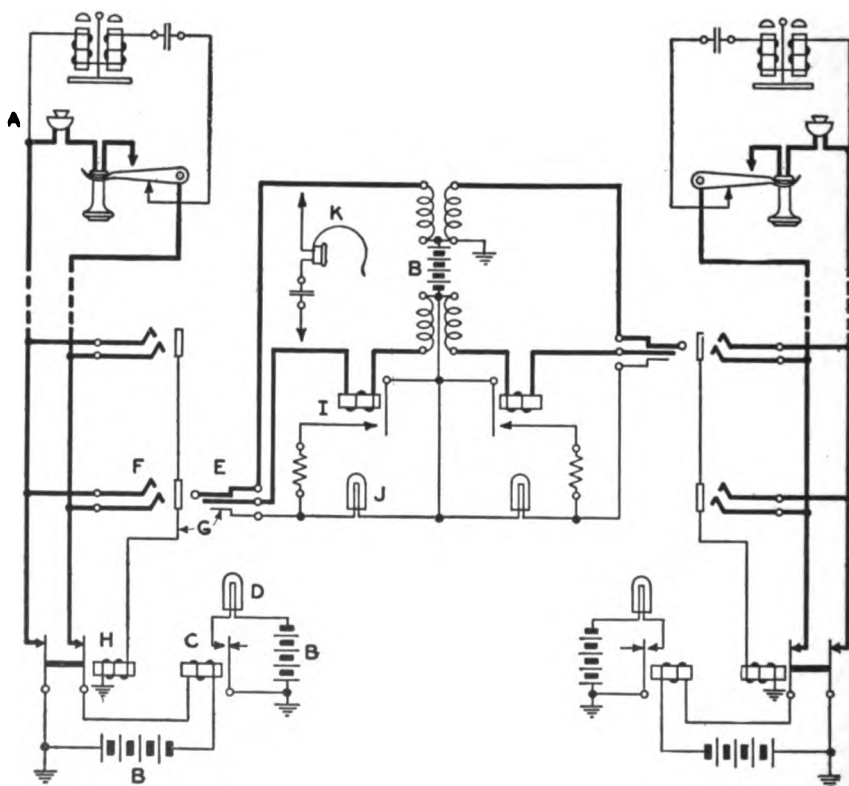


FIG. 44—SIMPLIFIED CIRCUIT DIAGRAM FOR MODERN COMMON BATTERY SYSTEM

that the subscriber desires to make a call, and she inserts plug E in jack F. This completes the sleeve circuit through G and operates cut-off relay H, opening the circuit through C and extinguishing line lamp D. At the same time, the talking circuit (indicated by heavy lines) is completed and supervisory relay I is operated, shunting supervisory lamp J before it has time to light. The operator then connects subscriber A with the desired party by means of the other side of the cord circuit, first making a busy test to determine whether or not the line is in use. K shows the operator's set in position to be connected for the busy test.

For the sake of simplicity, the ringing and listening keys and their connection into the cord circuit have been omitted from the diagram.

When A has finished his conversation, he restores his receiver to the hook, which opens the talking circuit and releases the armature of supervisory relay I. This removes the shunt around supervisory lamp J, which lights and notifies the operator that A has completed his conversation.

CHAPTER XII

HOW STATION APPARATUS BEGAN

THE first type of station apparatus was the box telephone illustrated in Figure 45. As will be seen by reference to the illustration, these instruments were not adapted to be held in the hand. Each had a single opening whereby it was used interchangeably as transmitter and receiver.

Figure 46 shows a later type of box telephone with the cover removed. The diaphragm was of sheet iron, and a striker, resembling the hammer of a bell, was so placed within that when operated by a push button, which appeared on the outside of the box, it would strike the diaphragm. When the user wished to signal the telephone station at the far end of the line (which had the coils that actuated its diaphragm permanently connected into the line), he pushed the button of his box telephone repeatedly, thus causing the hammer within his set to beat on the diaphragm of his instrument, and the sounds of these blows were transmitted over the line to the receiving instrument at the far end, where they were reproduced telephonically.

This, the first apparatus used for calling, was invented by Watson. It came into use in June, 1877, and was known as the Watson hammer signal, or "thumper." Before it was invented, the only means of signaling to the distant end of the line had been by tapping on the front of the diaphragm with a pencil.

The box telephone was followed in August, 1877, by the box wall telephone, in which the pole-pieces and mouthpiece were placed at right angles to the magnet instead of in line with the latter as had been the case in the original box telephone. This was the first commercial form of wall telephone.

As soon as the hand telephone came into existence, one of these instruments was used at each station both for talking and listening. It was found that many persons became confused when using the telephone, so that it was necessary to caution them "not to listen with their mouths or to talk with their ears."

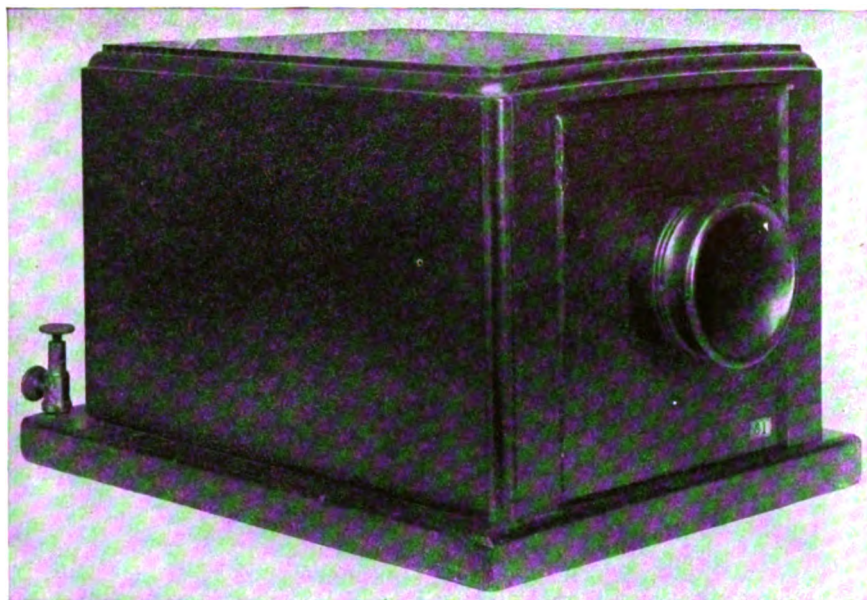


FIG. 45—Box Telephone. First commercial telephone, used in 1877. This instrument served as receiver, transmitter and calling device. It was placed upon a shelf or a table and the single opening was utilized for talking and for listening.

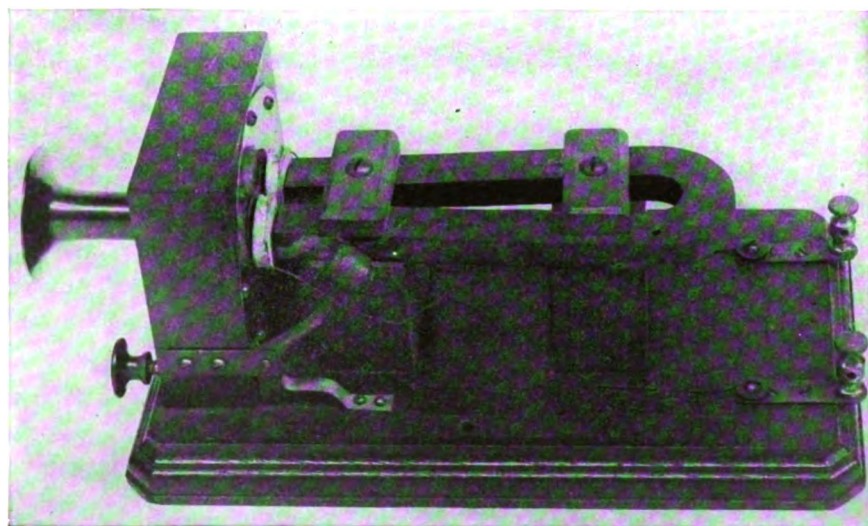


FIG. 46—Later form of box telephone with cover removed, showing push button and hammer of Watson's "thumper." This instrument employed a trumpet-shaped mouthpiece.

To remove the cause of this confusion, it soon became the practice to equip the station sets with a pair of telephones (Fig. 47), one to be held to the mouth for talking and the other to the ear for listening.

Following the use of the "thumper," electric tap bells or ordinary electric vibrating bells, or, in some cases, telegraph sounders were used for signaling. These electric bells left much to be desired on account of the limited length of line over which batteries of a reasonable voltage could operate the bells and the frequent attention which the batteries and bells required.

In 1878 Watson devised a calling mechanism termed a "buzzer." * This apparatus consisted of a large induction coil and a flat steel spring which the operator could cause to vibrate by the hand operation of a lever, making and breaking the primary circuit of the induction coil. This action sent an alternating current from a battery over the subscriber's line, causing his telephone to emit a loud sound.

The "buzzer" was succeeded later in the year 1878 by Watson's improved call bell, or ringert† (Fig. 48), adapted to be operated by an alternating current.

In structure it consisted of two gongs, with a striker playing between them. The striker was attached firmly to a horizontal, centrally-pivoted armature, which was placed above and close to the poles of an electromagnet. This armature was polarized in order that it should oscillate when an alternating current passed through the winding of its electromagnet, thus ringing the gongs in rapid alternation. It was practically a small synchronous motor. Its chief merit lay in avoiding the troubles which occurred in the vibrating bells with which moving contact points made and interrupted the current at every blow of the clapper. While the modern call bell embodies many advances over the original design of Watson, the principle, which he was the first to employ, is still universally used.

In the same year, 1878, Watson designed a small dynamo-electric machine (Fig. 49), consisting of a powerful permanent magnet with an armature of two coils of wire mounted on opposite ends of a rotatable bar, which the subscriber was enabled to spin rapidly by means of a wheel and crank. This machine generated at one end of the line the alternating current which operated the call bell at the other end.

* U. S. Patent No. 199,007, January 8, 1878.

† U. S. Patent No. 210,886, December 17, 1878.

These two devices—the call bell and the magneto-electric generator—were used in early commercial subscribers' sets.

Several manufacturers, licensed under the Watson patents, manufactured call-bell sets. These were Charles Williams, Jr., of Boston; E. T. Gilliland, of Indianapolis; Post and Company, of Cincinnati; Davis and Watts, of Baltimore; and the Electric Merchandising Company, of Chicago.

For a few years the subscribers' station signaling apparatus varied, some exchanges using magneto-electric generators for calling and some using keys to connect the transmitter battery to the line to furnish the current for signaling the central office.

By 1881 it was stated, at a meeting of the National Telephone Exchange Association, "of the two systems of call bells which have been in general use, *viz.*, magneto and battery, the former is now so rapidly superseding the latter, that only one of all the exchanges from whom reports have been received, recommends the battery system and does so simply for its own use."¹

As early as 1877 it became evident that a switch of some kind was needed, so that the signaling apparatus at a subscriber's station might remain normally connected to the line, ready for the call bell to be rung, but capable of being easily disconnected from the line and its place taken by the talking and listening instruments, whenever it was desired to do so. Hand-operated switches were used at first for this purpose, but it was soon found that the user was prone to leave his switch in the wrong position.

In 1877 Hilborne L. Roosevelt, a prominent organ builder of New York, and one of the founders of the first telephone company in that city, overcame this difficulty by inventing a lever switch provided at the outer end with a hook upon which to hang the hand telephone. The weight of the receiver held the hook down and, when in that position, it placed the circuit in condition to receive an incoming signal. When the hand telephone was lifted from the hook, a spring caused the latter to rise into a position, where, by making and breaking suitably arranged spring contacts within the set, it opened the circuit of the call bell and closed the necessary contacts for talking. Roosevelt secured a basic patent* on this device. His application was filed on October 3, 1877. Figure 50 shows an early form of

¹ Ref. (36), p. 92.

* U. S. Patent No. 215,837, May 27, 1879.

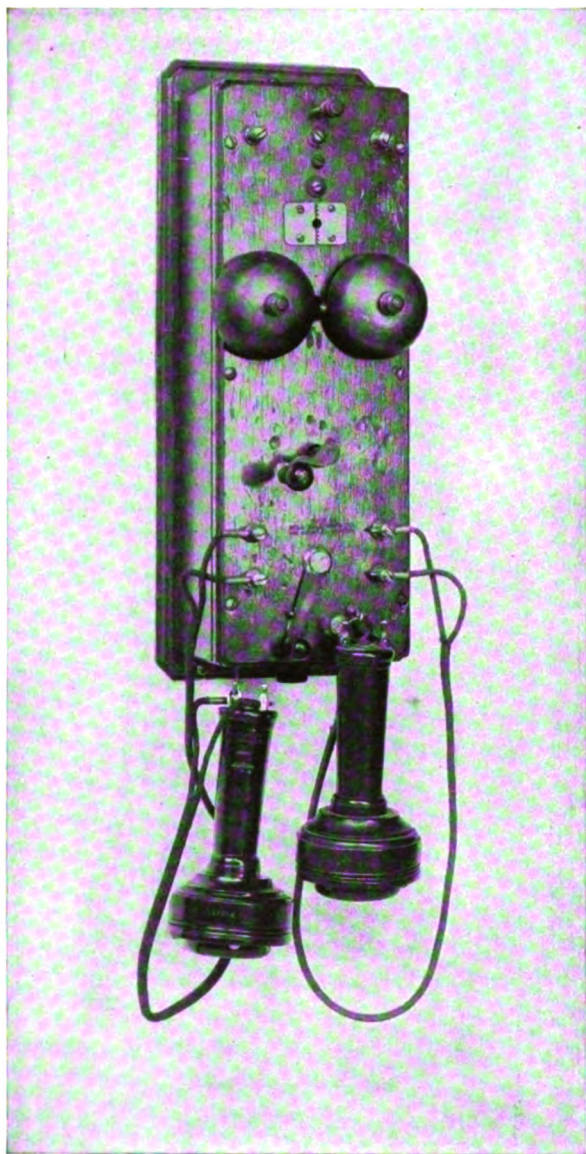


FIG. 47—Early form of station wall set equipped with a pair of telephones; one for talking, the other for listening. This set contained the polarized ringer and magneto-generator, the crank of which may be seen below the center of the box. Above the ringer gongs is the toothed lightning arrestor. The switch at the bottom of the set changed the circuits from the “calling” to the “talking” arrangement.

substation set in which the Roosevelt hook-switch was used. This was one of the earliest, if not the earliest, substitution of an automatic, for a manually operated device, in telephony. Watson, in 1880, invented * an improved form of automatic hook-switch which was arranged to cut out the secondary of the coil when the receiver was on the hook.

In Bell's early experimental work with the telephone, current for operating the transmitter was furnished by a battery placed in series with the line. An important improvement was made by introducing induction coils at each end of the line, and connecting each transmitter in series with the primary winding of an induction coil and a local battery, the secondary windings of the induction coils being connected in series with the receivers and the line. The effect of this change was to permit the use of local batteries of low voltage, and to put each transmitter in a local circuit of low resistance, thus creating a larger flow of current through the transmitter than would have been possible without an induction coil, and allowing the transmitter to operate under better circuit conditions.

This large variable current in the primary circuit was, by means of the induction coil, transformed into a relatively small current at considerably higher voltage in the line by reason of the large ratio of the number of turns in the secondary winding of the induction coil to the number in the primary winding.

There has occurred, from time to time, considerable discussion and debate involving the question whether Berliner or Edison is entitled to the credit for first proposing this use of induction coils in telephony. The writer does not intend to thrust himself into this discussion, but will merely state a few facts.

Berliner has said:

"I procured a small induction coil ordering the same through a firm in Washington (S. Oppenheimer and Company) in May, 1877, and for the purpose of testing its usefulness as a continuous current transformer, I proceeded as follows. . . . Thereafter, I always used a coil at each end, each primary in circuit with a contact telephone and a small battery (2 cells), both secondaries being connected to one another through the line." ²

* U. S. Patent No. 270,522, January 9, 1883.

² Letter of E. Berliner.

Berliner's induction coil patent (U. S. No. 199,141) was filed October 16, 1877, issued January 15, 1878, and reissued December 14, 1880.

Edison's patent (U. S. No. 203,013), noticeable for its inclusion of the induction coil, was filed December 13, 1877 and issued April 30, 1878.

After Watson had produced the magneto bell, or ringer, it became the custom, on party lines, to connect the sets, including the ringer coils, in series. It was found that the ringer coils caused considerable obstruction to the passage of the telephone talking currents. The more ringers that were connected in the line circuit, the poorer was the talk. This was due to their impedance which resulted from the many turns of wire on the cores of their electromagnets. At first it was sought to overcome their injurious effect by shunting their coils with a high resistance, through which the talking current might pass, although the alternating current, for ringing the call bells, would still pass through the ringer coils and operate these devices.

In 1882 W. A. Jackson, of Detroit, told the following to an assemblage of telephone men:

"Where we have intermediate stations on the lines we have been careful to arrange the call bells, or whatever may be in circuit, with the 'Jones Shunt.' I presume the Jones shunt is familiar to you all. It is simply a coil of German silver wire, connected at each side of the electromagnet and the call bell, and overcomes the retardation or induction from the cores of the magnet by shunting the circuit around the magnet itself. We have found that the application of this shunt has improved the working of the lines.^a . . ."

The complete solution of this difficulty did not come until 1890, when Carty made his invention of the bridging bell (U. S. Pat. No. 449,106, March 31, 1891). Carty's principle was to remove the series ringer coils from the line, to wind more turns of wire upon their electromagnets so as effectively to render them opaque to the passage of voice-frequency currents, and to connect them in multiple across the line instead of in series with it. This allowed the talking current to pass along the line, unimpaired by the effect of the ringer coils. It was this noteworthy invention which made possible the successful

^a Ref. (37), p. 58.

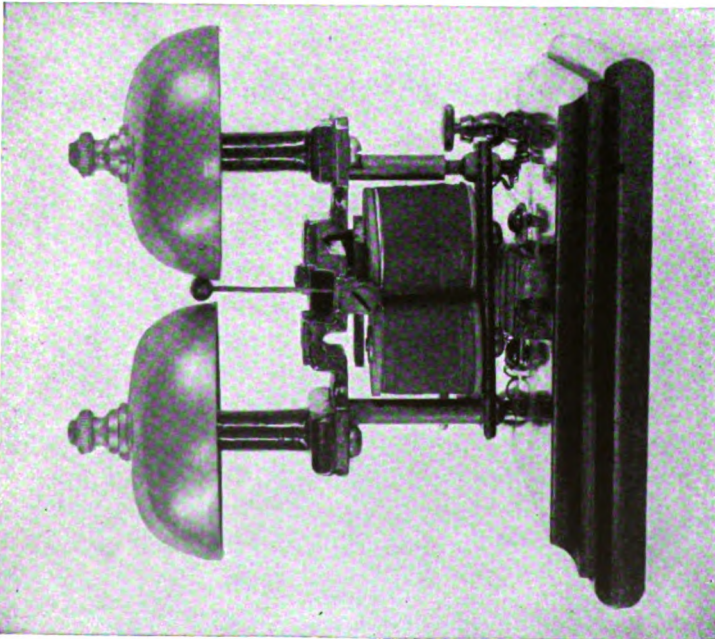
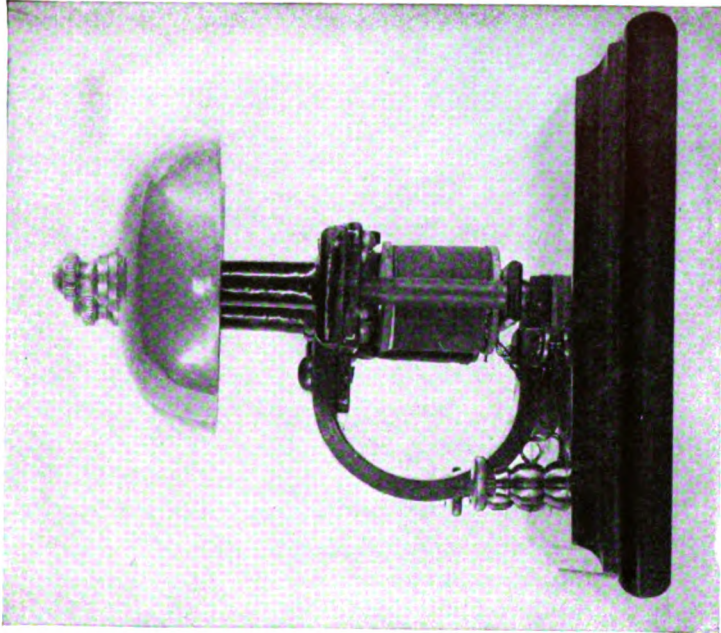


FIG. 48--Watson's Polarized Call Bell or Ringer.

use of party lines, and to Carty is due the homage of the American farmers to whom the rural telephone party line has meant so much in the way of bringing them in touch with neighbors, market centers, physicians, and others.

In 1878 the only electrical protective measures used in telephony were lightning arresters, adopted from telegraph practice. These consisted either of fine copper wire or of two metal plates, separated by a narrow air gap. One of these metal plates was electrically connected with the telephone line and the other was connected to earth. The principle of this device was that when the electrical potential of the telephone line was raised, as the result of a discharge of lightning, sparking would occur between the plates, allowing the electrical charge on the line to pass harmlessly to ground. In some forms of lightning arresters one of these plates was provided with a saw-toothed edge in order to facilitate the sparking.

Beginning about 1880 electric lighting systems began to come into use in cities. At first these were direct current systems of relatively low voltage, but they were soon followed by alternating current systems operating at considerably higher voltages. At that time neither the telephone nor the electric lighting wires were run with great skill, and accidental contacts frequently occurred between wires of the two classes.

This often caused to pass through the delicate telephone apparatus, electrical currents of much greater strength than the apparatus could safely conduct, with the result that, under these conditions, the telephone apparatus would become unduly heated and therefore create a fire hazard or frequently be destroyed. The ingenuity of telephone engineers was severely taxed to devise apparatus which would function to protect the coils of fine wire, which they had to employ in call bells and other apparatus, against these stray foreign currents. There were two obvious ways of attaining this protection. One was to use a fuse wire that would melt and open the circuit before the current attained a strength which would endanger the apparatus. The other was to use some sort of heat-controlled device that would operate to short-circuit the apparatus when the temperature of its coil was raised to an abnormal point.

To meet the latter condition, I. H. Farnham, in 1887, patented* a device in which a small ball of wax or pitch was placed in contact

* U. S. Patent No. 360,570, April 5, 1887.

with the electromagnetic coil of the piece of apparatus to be protected. This ball, on the side diametrically opposite its point of contact with the coil winding, normally held back a stiff spring which, when released, would move against a metallic contact so connected as to short-circuit or shunt the piece of apparatus to be protected, the idea being that, as the temperature of the coil rose, the wax ball would melt, allowing the spring contact, which it normally held open, to close.

An example of the former condition was Hibbard's fuse, patented * in 1888. This consisted of a thin, narrow strip of fusible metal, like tin foil, made extra narrow in one part to facilitate melting, and wrapped within a roll of asbestos.

One of the first inventions pertaining to enclosed fuses was made by T. N. Vail in 1885,† covering a fusible wire enclosed in a non-conducting, transparent case.

In 1891 Hayes and White patented ‡ a tubular fuse having a detachable stopper inserted in the side of the tube and adapted to be discharged on the operation of the fuse.

There were two principal causes of trouble connected with the operation of fuses. One was the tendency for an arc to establish itself between the terminals of the fuse, following its operation, thus permitting the dangerous current to continue to flow; the other was the tendency for the fuse to operate with a loud explosive noise which was disconcerting to any one who might be in its neighborhood.

A forward step was taken when the fuse was enclosed in a tube of insulating material open to the air at one end. With this arrangement, the expansion of the air within the tube, and the volatilization of the metal of the fuse wire itself, caused any incipient arc literally to blow itself out. The explosive noise resulting from the operation of the fuse was greatly reduced by enclosing the fuse wire ** within a jacket of braided asbestos.

The crude lightning arrester consisting of adjacent metal plates was superseded by two carbon blocks, accurately maintained a minute distance apart by a thin separator of mica, placed between them. As in the older form, one of these blocks was connected to the line; the

* U. S. Patent No. 377,073, January 31, 1888.

† U. S. Patent No. 322,214, July 14, 1885.

‡ U. S. Patent No. 458,753, September 1, 1891.

** U. S. Patent No. 550,638, December 3, 1895, A. H. McCulloch.

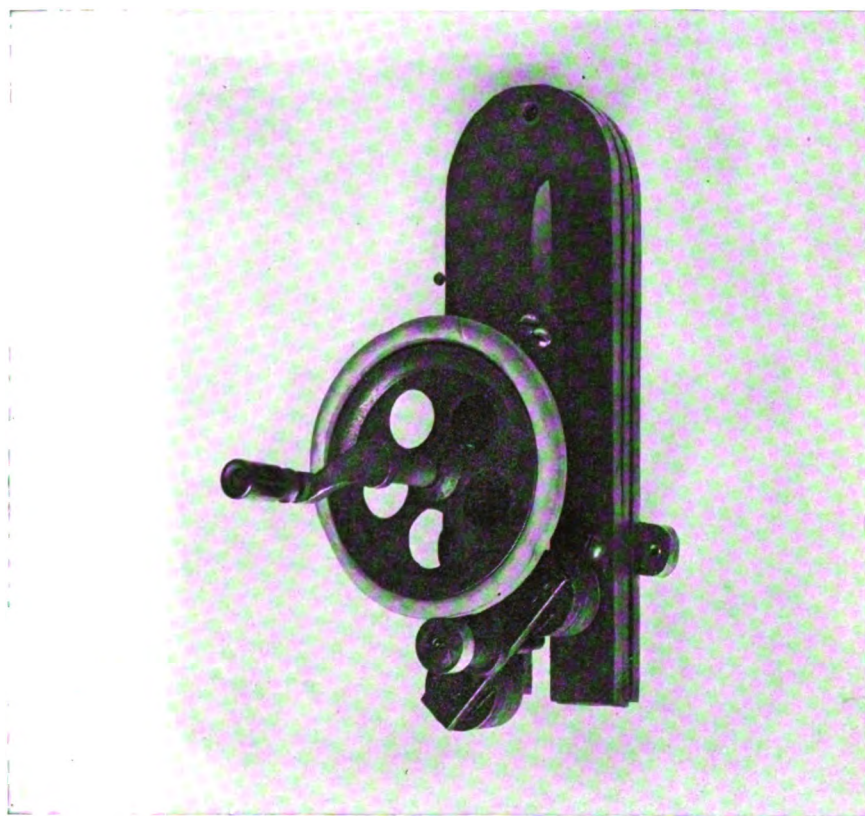


FIG. 49—Hand-operated alternating current generator designed by Watson for operating the polarized ringer at a distant station. It also served to operate the line signal or annunciator at the central office switchboard.

other to ground. Their operation was improved by inserting into the surface of one of the carbon blocks a bit of fusible metal.*

When an arc persisted between the blocks, enough heat was generated to melt this bit of fusible metal, allowing it to short-circuit the blocks and cause a fuse, placed in the circuit, to operate.

There still remained the risk of overheating delicate apparatus by "stray" currents that were too small to operate the fuses or of insufficient voltage to jump the gap between the carbon blocks. These "sneak" currents, if allowed to flow uninterruptedly, threatened to destroy the apparatus and impair the service.

The ultimate successor of the "wax-ball" protector was a device known as a "heat coil," developed by H. V. Hayes and W. L. Richards, which introduced into the line circuit a small coil of insulated wire wound on a fine copper tube within which a pin was soldered with low-melting alloy. When the "sneak" current flowed through this coil, sufficient heat was generated in the winding and conducted through the walls of the copper tube, to melt the special solder, allowing a spring that bore against one end of the pin to force the latter out of its normal position sufficiently to make contact with a ground plate, thus grounding the line and diverting the "sneak" current.

Electrical protective devices were also required and used at telephone central offices, to prevent injury to the switchboard apparatus.

Following the introduction of the common battery system, in which the coils of the call bell at the subscriber's station were placed in series with an electrical condenser, the use of the heat coil at the subscriber's station was discontinued, but it continued to find a place in the protective apparatus at the central offices.

The desk telephone first came into use at subscribers' stations in 1886. Its design was improved from time to time. Figure 51 shows the styles of desk stands that were developed and first used in the years 1886, 1892, 1895, 1897, and 1900.

Selective Signaling on Party Lines

Various modes of signaling a selected station, on a line common to several stations, had been devised, in connection with telegraph practice, before the invention of the telephone. Included among these were step-by-step arrangements, systems depending for their operation

* U. S. Patent No. 438,788, issued to A. C. White, October 21, 1890.

upon variations in current strength, and synchronized clockwork mechanisms wherein revolving cams connected the main wire with various branches for definite periods of time. Much work on harmonic telegraph systems had also been carried forward by Bell, Edison, Gray, and Rowland.

The impetus given to inventors of selective signaling arrangements by the invention of the telephone is revealed by the fact that no less than 160 United States patents were granted for telephonic selective signaling devices between the years 1879 and 1891. Much of the information that follows, with reference to early selective signaling systems is from T. D. Lockwood's paper entitled "Selective or Individual Signals," delivered before the American Institute of Electrical Engineers, in 1892.

The various types of telephonic selective signaling systems that had been invented by the year 1882 may be classified broadly as follows:

1. Signals at substations operated by currents of different strength. (Buell, U. S. Patent No. 221,512, November 11, 1879.)
2. Signals arranged to respond to currents of opposite direction. (Anders, U. S. Patent No. 218,153, August 5, 1879.) This was the invention of G. L. Anders, an employee of the National Bell Telephone Company. It was basic to all selective signaling systems employing polarized bells. Anders's first claim read:

"In a magnetic bell circuit consisting of a central and two bell stations, the combination at each bell station of a polarized armature and bell hammer, the polarization of the two armatures being in opposite directions, substantially as described, so as to ring either of the two bells without ringing the other, according to the direction of the current."

The bells at the two stations were similar in every respect except that the armatures were of different polarities. The operator at the central office employed a double key to send either positive or negative current from a battery over the line.

3. Signals involving changes both in the strength and the direction of the signaling currents. (Anders and Vail, U. S. Patent No. 242,408, May 31, 1881.)
4. Electromagnetic step-by-step devices, acting to bring the sub-

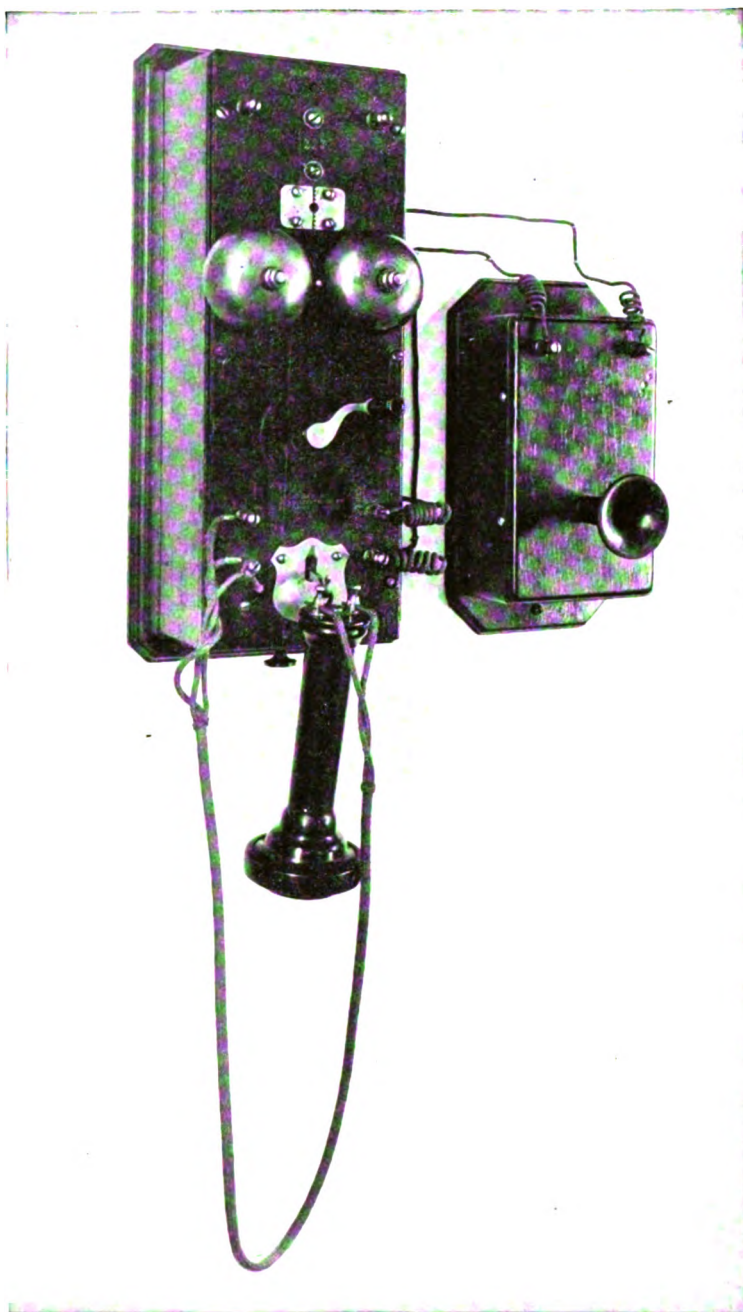


FIG. 50—Early Form of Wall Telephone Set, Equipped with Automatic Hook-Switch.

station signals to a ringing point differing for each substation, and then to close a local circuit, including the bell, to operate the ringing mechanism. (Dickerson, U. S. Patent No. 212, 792, March 4, 1879; Curtis and Crocker, U. S. Patent No. 230,530, July 27, 1880.)

This type of system, adapted to as many as twenty stations on a line, was employed to some extent by the Stromberg-Carlson Company.

5. Clockwork Bells.

- (a) Employing a constantly running clock-train to bring the various substation bells into the circuit successively, or to remove a mechanical holder from their hammers. (Bliss, U. S. Patent No. 223,469, January 13, 1880).
- (b) Employing a normally stopped clock-train at each substation. All clocks were started by the same initial pulsation and brought their signals to ringing points or their bells into circuit at different times. (Blake, U. S. Patent No. 232,442, September 21, 1880).
- (c) Employing a normally quiescent clock-train controlled by an electromagnetic escapement and permitted to move by successive beats as a key at the central office alternately made and broke the circuit. (Eaton, U. S. Patent No. 228,047, May 25, 1880.)

6. Arrangements operated by an electromagnetic ratchet and pawl, wherein all of the bell hammers were moved forward to strike at the same time, but all, except the desired one, were prevented from striking by an obstacle, interposed mechanically. In the case of the bell at the station which it was desired to call, this obstacle was removed. (Anders, U. S. Patent No. 219,059, September 2, 1879.)
7. Systems in which the ringing was done by means of a special circuit arrangement of conductor combinations, two series of circuits radiating from a central office to a number of substations, and one of each series caused to enter all stations, no two stations, however, having the same two circuits. Only when the current traversed both circuits would the bell be rung at the station which they entered. This system provided for two relays at each station whose concurrent action was neces-

sary. (Vail, U. S. Patents No. 219,188, September 2, 1879, and No. 224,855, February 24, 1880.)

8. Substation signals in which galvanometers were employed. Different strengths of current sent over the line would produce different deflections of the galvanometers, and each station had its individual ringing point at a different deflection. (Southworth, U. S. Patent No. 262,252, August 8, 1882.)

Of these several types of systems, the Anders system is the only one that ever attained commercial importance.

The first feasible system for harmonic signaling over telephone lines was devised by J. B. Currier.* It was used to a limited extent in New England for a number of years. In Currier's system, a number of pendulums of different lengths, operated by electromagnets, were employed in the central office to make and break the ringing circuit at different rates of speed, or frequency. At the substations electromagnets with armatures bearing hammers to ring the gongs and tuned, each to a different frequency, were employed. When it was desired to ring one of the bells to the exclusion of all the others, an interrupted current of a frequency corresponding to that particular bell was sent over the line.

The next important step in harmonic ringing was made by J. A. Lighthipe, an employee of the Bell Company on the Pacific Coast, in 1895.†

At that time, metallic circuits had come into extensive use, and the Carty bridging bell had done away with the practice of connecting the electromagnets of call bells into the line in series. Lighthipe employed a battery and an interrupter arrangement for supplying the ringing current. The first claim of his patent read as follows:

"The combination with a telephone line connected with the secondary of a transformer, of a local circuit containing a source of electricity and two parallel circuits or paths, an electromagnet provided with two opposed windings, one winding being included in each of said parallel paths, two primary windings for said transformer, one included in each of said paths, a reed adapted to vibrate in front of the poles of said electromagnet, and contacts controlled thereby for intermittently opening and closing

* U. S. Patent No. 251,097, December 20, 1881.

† U. S. Patent No. 550,982, December 10, 1895.

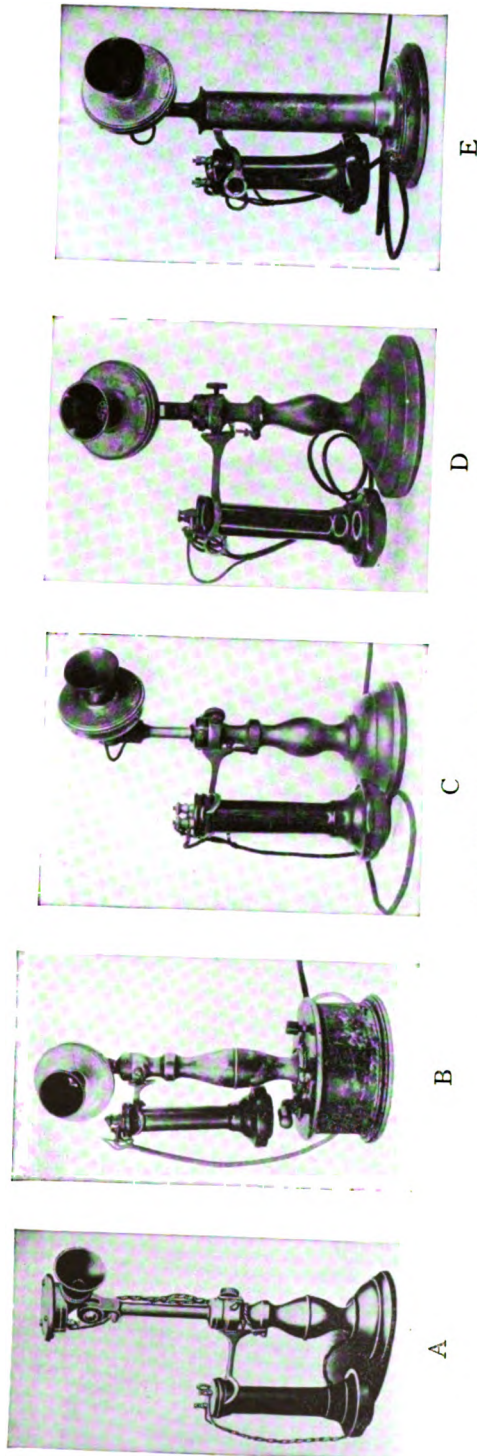


FIG. 51—EARLY DESK STANDS

A. Style in use in 1886, equipped with "Long-Distance" transmitter. The switchhook contacts and transmitter wiring were exposed.

B. Style in use in 1892. The push button in the base served to connect to the line, for signaling purposes, a circuit connected to a central source of ringing current. The key at the left served to connect the set with either of two lines. A solid back transmitter was employed. The wires from the transmitter were placed within the standard of the desk stand to protect them from injury.

C. Style in use in 1895.

D. Style in use in 1897. The switchhook terminated in a closed ring instead of horns, to avoid injury to the receiver diaphragm.

E. Style in use in 1900. The switchhook contacts were protected by being placed within the set.

the circuit through one of said paths whereby intermittent or vibratory currents are produced in the telephone line."

At the substations the bells were bridged across the circuit, with a condenser in series with each. The armatures of the ringers were tuned to respond to the proper frequencies.

This system was used on the Pacific Coast for several years and is, in its essentials, similar to the harmonic systems which have found considerable use in later years, chiefly in the independent field.

The first patent* on divided two-party ringing was issued to F. A. Pickernell, of the American Telephone and Telegraph Company, in 1893. It provided for connecting one substation bell to ground from each wire of a metallic circuit line, and was arranged for use with the branch terminal multiple switchboard, the ringing current being supplied from an alternating current generator.

The first commercial system for four-party full-selective signaling was devised † by A. S. Hibbard, of the Chicago Telephone Company, in 1896. Two oppositely biased polarized bells were connected from either side of a metallic circuit to ground.

The biasing of the bells was accomplished by means of a light spring so acting upon the pivoted armature as to retain the latter normally in the position toward which it would be attracted by pulses of current in a direction not intended to operate the bell.

With two ringers oppositely biased in this manner and both connected to ground from one wire of the line, a pulsing plus or minus current could be sent over that line wire so as to operate selectively the ringer adapted to respond to the current sent out in a predetermined direction, the other ringer meanwhile remaining unresponsive, as the current sent out to operate the former assisted the biasing spring of the latter to prevent its armature from oscillating. Two generators were provided at the central office, one having its positive pole grounded and the other its negative pole. This system was used to a considerable extent, particularly by the Chicago Telephone Company. Its principal difficulty lay in its application to common battery operation. The relays controlling the line and supervisory signals of the common battery switchboard had to be kept within the proper marginal adjustment so as to work properly through the resistance of

* U. S. Patent No. 511,276, December 19, 1893.

† U. S. Patent No. 555,725, March 3, 1896.

the line and talking apparatus, but not through the resistance of the line and the substation bells.

This limitation was removed by an invention* of G. K. Thompson and E. C. Robes, of The American Bell Telephone Company. In their system, the bells, with their ground connections, were normally detached from the line; but they were brought into circuit, during the operation of ringing from the central office, by means of alternating current relays in series with condensers. This arrangement has been widely used in four-party selective systems.

Another four-party full-selective system, known from the initials of the inventors as the "B. W. C." system, was devised† by Messrs. J. A. Barrett, G. W. Whittemore, and W. M. Craft, employees of the American Telephone and Telegraph Company. Their system depended for its operation on the sending of currents of either polarity over either, or both, of two line wires, in combination with each other or with ground. It gave eight theoretically possible signaling combinations. It was used to some extent, but, due to its complications, it was a difficult system to maintain in satisfactory adjustment.

The next important step in the development of four-party selective signaling systems was the replacing of the pulsating ringing generators by an alternating current generator connected in series with plus and minus batteries. This feature was patented‡ by T. C. Drake in 1904, and is used in modern systems.

* U. S. Patent No. 644,647, March 6, 1900.

† U. S. Patent No. 582,107, May 4, 1897.

‡ U. S. Patent No. 763,970, July 5, 1904.

CHAPTER XIII

THE BEGINNING OF THE PHANTOM CIRCUIT

THE name of "phantom circuit" has been given to the scheme which permits a telephonic talking current to be superimposed on two pairs of wires, each of which simultaneously transmits a telephonic conversation. This third, or phantom circuit, is obtained by connecting the two pairs of wires together, with suitable apparatus, in a peculiar way. After the phantom circuit has been properly constituted, it becomes possible to carry on simultaneously three independent and non-interfering conversations: one, between stations A and B, over one pair of wires; a second, between stations C and D, over the second pair of wires; and a third, between stations E and F, using the two wires of one of the pairs, in multiple as one side of the phantom circuit and the two wires of the second pair, also connected together in multiple, as the other side of the phantom circuit.

The idea of the phantom circuit started with an invention of F. Jacob.* This covered a plan of simultaneous operation of two telephone circuits, or one telephone circuit and one telegraph circuit on three conductors; three telephone circuits on four conductors; three telephone circuits and one telegraph circuit on five conductors, etc., suitable electrical balance of the circuits being attained by terminal arrangements of variable resistances or condensers, or by a combination of resistances and condensers.

Figures 52 and 53 show plans of these circuits. Referring to Figure 52, A and A₁ are two telephone stations connected by line wires L₁ and L₂. Telegraph or telephone stations T₁ and T₂ are connected to ground and to the line wires through the balanced resistances R₁ and R₂ of a Wheatstone bridge. Current flowing from T₁ or T₂ will pass in the same direction over L₁ and L₂, and R₁ and R₂, returning through ground. R₁ and R₂ being electrically balanced with respect to each other and to L₁ and L₂, no current will flow through A or A₁. Current originating at A or A₁ will flow in opposite direc-

* U. S. Patent No. 287, 288, October 23, 1883.

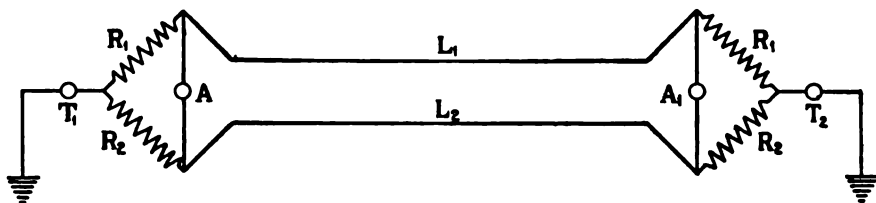


FIG. 52—PHANTOM CIRCUIT—F. JACOB
Intended for the simultaneous operation of two circuits.

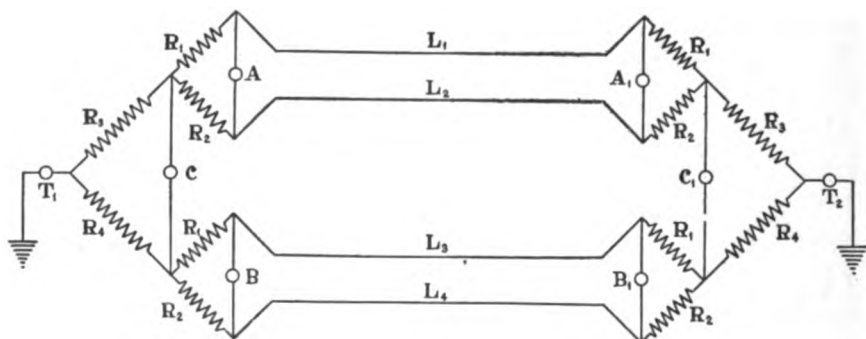


FIG. 53—PHANTOM CIRCUIT—F. JACOB
Intended for the simultaneous operation of three telephone circuits and one telegraph circuit.

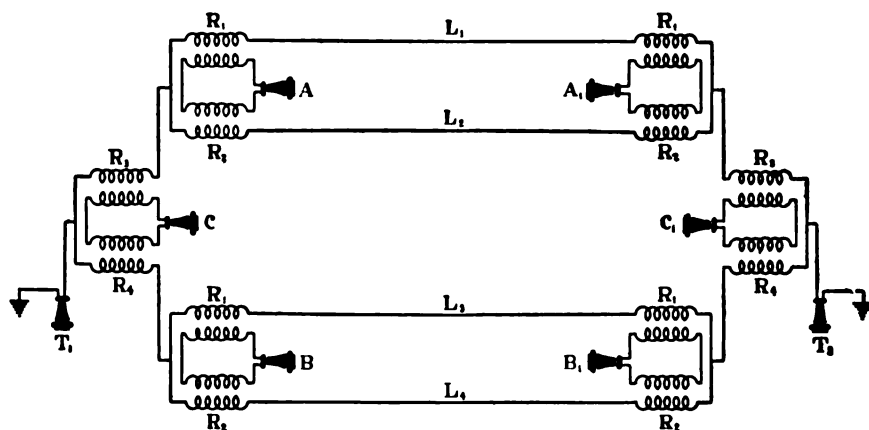


FIG. 54—PHANTOM CIRCUIT—J. J. CARTY
Based on the use of induction or repeating coils instead of resistances.

tions along L_1 and L_2 and through the telephones A and A_1 . Only a small proportion of the current will flow through R_1 and R_2 , on account of the high resistance they offer when connected in series. A and A_1 , and T_1 and T_2 may, therefore, be in communication, each with each, simultaneously without any interference of one circuit by the other.

Reference to Figure 53 will show similarly how two additional line wires may be connected by the Wheatstone bridge method and three telephone circuits and one telegraph circuit operated over the four wires and the ground return.

Attempts to adapt the Jacob system to commercial use in this country resulted in failure due to the impracticability of maintaining the required balance of the arms of the bridge.

It was found that this balance should be made with respect to inductance as well as capacity and resistance. In 1889 Pickernell proposed that impedance coils be used in place of the non-inductive resistances of Jacob. This resulted in the design of split impedance coils which gave approximate balance of inductance and resistance, and conversations were carried on over laboratory lines; but it appeared, in view of the difficulty of balancing the phantom circuit when the side circuits were idle, that there would be no hope of maintaining a balance when the side circuits were switched into connection with other lines, as a side circuit so used would be in electrical connection with another line whose capacity to ground would, in effect, be added to that of the side circuit, thus giving this side of the phantom circuit a greater capacity to ground than the other side, causing disturbing currents to flow in the phantom circuit.

Following the Jacob patent, a number of patents were granted F. Van Rysselberghe, A. M. and T. R. Rosebrugh, J. J. Carty, J. A. Barrett, T. O. Stockwell, and others, for systems of duplexing or multiplexing telephone lines. None of these systems except the Carty system has been found of value in connection with phantom circuits. The Barrett system resembled the Carty system, but Carty antedated Barrett. Carty's system* covered the use of phantom-circuit repeating coils, and this feature is a basic characteristic of the phantom-circuit system now in use. Figure 54 contains a diagram illustrating its principle of operation.

It differs from the Jacob system in that the bridge arms R_1 , R_2 ,

* U. S. Patent No. 348,512, August 31, 1886.

etc., are the primary windings of induction or repeating coils, and telephones, A, A₁, B, B₁, and C, C₁, are placed in the secondary circuits of the coils instead of being directly connected with the line wires. T₁, T₂ are the terminals of a superimposed grounded signaling circuit that may be used either for telegraphing or telephoning. With the primary coils balanced, the length of line in the secondary circuit can be varied without altering the balance of the phantom circuit, provided that the mutual electrostatic capacity of the two windings of the respective repeating coils is very low. However, at that time the theory of alternating current transmission was only partially understood even by those most advanced in electrical science. It was appreciated that extremely delicate and exact balances were required; but unforeseen difficulties were encountered in the attempts to make repeating coils of satisfactory balance, and the then state of the electrical art was not such as to enable any one, no matter how skilled in his profession, to comprehend the steps which needed to be taken to solve the problem. It was for this reason that the phantom remained, for many years, scarcely more than an interesting scientific curiosity.

In 1894 and 1895 Bell engineers conducted tests on phantom circuits, using both split impedance and repeating coils on interoffice trunk lines in underground cables, and, in the case of a few of the circuits, obtained fairly favorable results. Tests were made in 1899 on open-wire lines between Johnstown and Gloversville, N. Y., on which C. H. Arnold reported as follows:

"The trunks between Gloversville and Johnstown, in their present condition, cannot be commercially duplexed . . . because it would be impossible to ring on the duplexed trunks, because the phantom would be too noisy, and because there would be objectionable crosstalk on the phantoms and on certain trunks. . . . Before further duplex tests on aerial lines are made, systems of transpositions for duplexed lines should be worked out."

In the latter part of 1899 some coils were tested that were better balanced than any previously made and of higher ringing efficiency. These were tested on open-wire lines between Lewiston, Maine, and Berlin, New Hampshire. While they did not perceptibly interfere with ringing, the lines were too noisy for phantom use.

In the closing years of the last century, sporadic installations of phantom circuits were made by adventurous persons in both the In-

dependent and the Bell operating fields; but these were in localities and under circumstances where circuits of a high order of merit, with regard to noise and interference, were not a matter of first importance and, in such cases, results could be tolerated which, under more exacting conditions, would have been considered unsatisfactory.

In the latter part of 1902 and the early part of 1903, as the outcome of experiments conducted by the American Telephone and Telegraph Company with the cooperation of the New England Telephone and Telegraph Company, a phantom circuit was put into commercial operation between Lewiston and Berlin, the wires being transposed so as to eliminate, as far as possible, crosstalk and the noises that were introduced by exposure to disturbing causes. This circuit was used commercially for several weeks, and the operating forces reported that out of thirty commercial conversations over the circuit there were but six that were unsatisfactory to the parties talking. Considerable difficulty was, however, experienced in ringing over the phantom circuit when it was connected with another line. In 1903 new coils, of the toroidal type, replaced the coils originally used in this installation, and showed great improvement.

It was the impetus given to coil design by the exhaustive early work on loading that finally resulted in the production and use of phantom terminal coils of the toroidal type which, in connection with the working out of suitable plans for transposing the wires, put the use of the phantom circuit for open-wire lines on its feet.

The first transposition system for preventing crosstalk between phantom and other circuits was proposed by Carty.* As soon as well-balanced coils became available, improvement followed improvement in rapid succession, no less than eight phantom transposition specifications being issued by the Bell engineers in a period of about four years from 1904 to 1908.

In anticipation of the development of phantom circuit coils for cables, the question of the structure of a duplex cable was considered as early as 1894. In April, 1895, C. H. Arnold stated in a report that "the simplest arrangement of wires in a cable for multiplexing would seem to be twisted pairs twisted." This arrangement had been previously proposed by Carty.

The first installation of a cable containing pairs specially transposed for phantom working was between the John Street and Frank-

* U. S. Patent No. 399,377, March 12, 1889.

lin Street central offices in New York City in 1898. The arrangement used was unsuccessful in keeping the crosstalk between the phantom and side circuits within commercial limits.

Appreciating the desirability of phantoming circuits in cables, both to enable phantom open-wire lines to be brought into cities in cables and to attain the economies of phantoming in intercity cables, work was continued for several years on the problem of developing a practicable type of cable that would admit of phantoming. The problem was attacked from two standpoints: first, to produce cables having the high degree of symmetry and electrical balance required to prevent mutual interference; second, to determine whether cables, insufficiently well balanced as they left the factory, could be so connected together, length to length, during installation as to give satisfactory results.

It was in 1910 that the first practical loaded "quadded" cable was produced by specially twisting together two pairs of wires to form what is now termed a "quad." This cable was installed between Boston and Neponset, a distance of about six miles. While the manufacturing processes employed in that cable were refined in many ways, the cable, as it left the factory, was not sufficiently well balanced to permit good phantom operation without taking certain precautions. After installing the cable and before splicing the lengths together, the individual circuits in each length were carefully measured for electrical unbalance with apparatus specially designed for the purpose.

Acting on the information afforded by these tests, the circuits to be spliced together were so selected that unbalances existing in one cable length would, as far as practicable, be neutralized in adjacent lengths, thus producing a high degree of balance in the cable as a whole.

The results obtained with this initial installation of quadded cable were utilized in the cable placed in 1911, between Philadelphia and Washington, and, since that time, every important intercity cable has been so arranged as to permit of phantom operation.

As the electrical balance, obtained in the final stage as described above, was disturbed when cable lengths had to be replaced, in the event of injury, it was deemed undesirable to rely so largely on this balancing during installation, and means were sought to enable the cables to be better balanced when they left the factory. This was finally accomplished after continued effort extending over a period of

about four years. Every part of the manufacturing process was refined further, until the unbalances existing in the individual lengths of cable were reduced to a small fraction of those which occurred when the development work was begun. These improvements not only made it possible greatly to reduce the amount of special work required during the installation of the cables, but also resulted in improved transmission efficiency of the cables and in the ability to place more wires in a cable sheath of given size.

Among the patents bearing on quadded cables may be mentioned U. S. Patent No. 863,969, August 20, 1907, to the Englishmen, William Dieselhorst and A. W. Martin, the first claim of which reads:

“A method of making telephone and telegraph cable cores, which consists in twisting together pairs of individual conductors with a constant length of lay from end to end of each twisted pair, and again twisting the twin conductors in pairs but with a different length of lay.”

This patent was purchased by the Western Electric Company.

The loading of phantom circuits was covered in U. S. Patents No. 980,921, January 10, 1911 to G. A. Campbell and T. Shaw, and No. 981,015, January 10, 1911, to T. Shaw.

Improvements in quadded cable practice were covered in U. S. Patent No. 1,064,433, June 10, 1913, to O. B. Blackwell and G. A. Anderegg, covering the method of reducing disturbances between groups of adjacent conductors by determining the differences of capacities of the conductors of one group with relation to those of another group, and then so combining the capacities of the groups that they tend to balance; U. S. Patent No. 1,124,249, January 12, 1915, to G. A. Anderegg, covering a method of assembling wires to form a cable having low electrostatic capacity unbalances; U. S. Patent No. 1,167,677, January 11, 1916, to G. A. Campbell, O. B. Blackwell, and E. H. Colpitts, covering a method of capacity unbalance testing for equalizing capacities and eliminating crosstalk; and U. S. Patent No. 1,271,824, July 9, 1918, to G. A. Anderegg and W. E. Mougey, a basic patent covering a quad having quad twists shorter than one of the pair twists.

CHAPTER XIV

THE BEGINNING OF THE LONG-DISTANCE LINES

A vision into the future, not transcended even by Bell's address to the London capitalists, written in Kensington, England, March 25, 1878 (*vide* Chapter III), was contained in the Certificate of Incorporation of the American Telephone and Telegraph Company in these words:

"The general route of the lines of telegraph of said association will be from a point or points in the City of New York along all railroads, bridges, highways and other practicable, suitable and convenient ways or courses, leading thence to the Cities of Albany, Boston, and the intermediate cities, towns and places; also from a point or points in and through the City of New York, and thence through and across the Hudson and East Rivers, and the bay and harbor of New York, to Jersey City, Long Island City, and Brooklyn, and along all railroads, bridges, highways and other practicable, suitable and convenient ways and courses to the Cities of Philadelphia, Baltimore, Washington, Richmond, Charleston, Mobile and New Orleans, and to all intermediate cities, towns and places; and in like manner to the Cities of Buffalo, Pittsburgh, Cleveland, Cincinnati, Louisville, Memphis, Indianapolis, Chicago, St. Louis, Kansas City, Keokuk, Des Moines, Detroit, Milwaukee, St. Paul, Minneapolis, Omaha, Cheyenne, Denver, Salt Lake City, San Francisco and Portland, and to all intermediate cities, towns and places; and also along all railroads, bridges, highways and other practicable, suitable and convenient ways and courses as may be necessary or proper for the purpose of connecting with each other one or more points in said City of New York, and in each of the cities, towns and places hereinabove specifically or generally designated.

"And it is further declared and certified that the general route of the lines of this association, in addition to those hereinbefore described or designated, will connect one or more points

in each and every city, town or place in the State of New York with one or more points in each and every other city, town or place in said state, and in each and every other of the United States, and in Canada and Mexico; and each and every other of said cities, towns and places is to be connected with each and every other city, town or place in said states and countries, and also by cable and other appropriate means with the rest of the known world, as may hereafter become necessary or desirable in conducting the business of this association."¹

In scanning the annual reports, made by successive presidents of The American Bell Telephone Company to its stockholders, for a dozen years or so, starting with the year 1884, the writer has received a lively impression of the plans, hopes, and accomplishments that marked the gradual evolution of the Long Lines plant in the United States. It has therefore seemed to him that, by presenting to the reader, in chronological order, a series of extracts from these reports, the story of the beginning of the Long Lines can be told better than in any other manner.

President Forbes, in the report of March 25, 1884, stated:

"Especial attention is being given to long-line service, and we have just built a line between Boston and New York, now almost ready for trial; with this we shall see whether sufficiently good results can be obtained for commercial purposes, and if the result is satisfactory, we propose to have the experiment at once followed by the establishment of lines for public service between these and other points of importance."

In the succeeding report of March 31, 1885, President Forbes continued:

"The experimental line between Boston and New York has proved entirely successful. It was built with a metallic circuit of two copper wires (hard drawn No. 12), and was placed upon poles belonging to the several companies occupying the route via Providence. Conversation can readily be carried on in low tones, the speaker's voice being easily recognized. There can no longer be a question of the success of long-distance lines between all points within two hundred to three hundred miles of each other,

¹ Ref. (77), p. 349.

and even more, where the demand for such service is of a character to warrant the building of metallic circuit systems. Such systems will be very costly, and our present licensed companies are neither provided with capital nor organized for the purpose of undertaking a work of the proportions which commercial success in this business will involve.

"It therefore becomes necessary for our company to take the lead in building lines of connection between the large cities, and a beginning will be made this summer between New York and Philadelphia."

From the report of President Forbes of March 30, 1886:

"During the year a pole line has been built between New York and Philadelphia, with a capacity of seventy wires, and twenty-four copper wires placed upon them, various sizes being taken for purposes of experiment. Some difficulty has been found in securing rights of way for this line. Sufficient facilities are not yet secured in Philadelphia for reaching customers there, but it is expected that this will soon be accomplished, so that the question of commercial demand between two large cities a hundred miles apart will presently have a fair test. The Metropolitan Company, of New York, pays for and owns over one-half of this line, and will divide the expenses and receipts with us. The line is practically completed, and, with twenty-five wires, will cost about \$215,000.

"In our report last year it was mentioned that additional capital would be needed for this business; and that we had applied to the Massachusetts Legislature to authorize an increase in our stock. As this was refused, and the volume of the business, if successful, will need capital far beyond the amount of our unsold stock, we have been obliged to make other provision for developing this important branch, and have organized a company under the laws of New York for this purpose, called the American Telephone and Telegraph Company.

"Mr. Vail has been made President of the company, and has general supervision of its work. Mr. E. J. Hall, Jr., is the general manager, with immediate charge. As soon as sufficient encouragement is received to continue building these long lines, the above

company is prepared to build between Boston and New York, and other important points."

From the March 29, 1887, report, the last made by President Forbes:

"Terminal facilities have finally been secured, within a few months, in Philadelphia, for the long line service, and arrangements completed for giving facilities for conversation to New York and other important points. Several private lines are already under contract between Philadelphia and New York, and we shall this year be able to go far in ascertaining the value of this class of business.

"The delay in getting facilities granted in Philadelphia has prevented us from determining this question in a practical manner; but we consider it of sufficient importance to connect Boston with New York to warrant building that line without waiting for the commercial result in the Philadelphia and New York line, and are taking steps to complete it during the present year."

President Howard Stockton, in the March 27, 1888, report, stated:

"The long-line service has been extended from New York to Albany, and to Boston, making a total of 550 miles of pole lines and about 10,000 miles of wire. The success electrically, as well as commercially, has been beyond our expectations.

"The income from the long lines is now more than sufficient to meet the current expenses, and there is every reason to expect that before next year it will pay a moderate profit. The great cost of the plant is to be borne in mind in considering the direct profit from the long-line service, but the importance of the system as a safeguard to our business cannot be overestimated.

"It is intended to complete this year the lines between New York and Boston, to extend from Albany towards Buffalo, and to build a line from Chicago to Milwaukee. The estimated cost is about \$1,000,000."

From President Stockton's report of March 26, 1889:

"The lines of the American Telephone and Telegraph Company have been extended during the year 1888 from Albany to Buffalo, and new lines have been built from Chicago to Milwau-

kee, and from Boston to Providence. An additional pole line has also been constructed between New York and New Haven. Altogether, about \$2,200,000 has been spent on the long lines, which now comprise 26,038 miles of wire. The greater part of this money has been obtained by the issue on the first of August last of \$2,000,000, 7% debenture bonds of the American Bell Telephone Company, which were offered to the stockholders at par. The whole amount was subscribed for, except 12 bonds of \$1,000 each, which were afterward sold at auction.

"The service on the long lines has been excellent and the business is increasing, but the best results cannot be expected until the principal exchanges shall have adopted the metallic circuit system; exchange subscribers in the cities connected by the long lines will then be able to converse directly through their exchange instruments.

"Besides the direct profit from the long lines, there have been important indirect advantages resulting from their construction. Wherever they have been built, the local companies have adopted a higher standard of construction and service and their extra-territorial tolls have greatly increased.

"The success of the long lines has convinced your Directors that the system should be extended. To provide money for the work and for other contingencies, the Legislature has been asked to authorize an increase in the capital stock of the American Bell Telephone Company. The advantage to the public of the proposed development and extension is so plain that we hope it will be generally approved."

Continuing from President John E. Hudson's report of March 25, 1890:

"During the year the American Telephone and Telegraph Company—the long line company—has continued the extension and development of its scheme of lines. It has extended its work from Philadelphia to Baltimore and Washington. It has also completed a second line from New York to Boston, building in 1889 the part from New Haven to Boston, and has entered eastern Pennsylvania, building lines connecting Philadelphia with Reading, Easton and Scranton. It has connected with its eastern lines Newport, R. I., and Fall River and New Bedford, Mass."

From the March 31, 1891, report of President Hudson:

"The American Telephone and Telegraph Company—the 'Long Line' Company—has during the year constructed, in extension of its system, the following lines:

"From Scranton, Penn., to Syracuse, N. Y., with branches to the principal towns in Eastern Pennsylvania and central New York; from Buffalo, via Erie, Penn., south to New Castle, Penn., taking in the towns of Western New York and Western Pennsylvania. The second line, from New York west, was substantially completed, via Easton and Reading, to Harrisburg, Penn.'"

Next, from President Hudson's annual report of March 29, 1892:

"The construction work of the 'Long Line' Company—the American Telephone and Telegraph Company—in the completion and extension of its system has included the building of a pole line from Pittsburgh to Harrisburg, and of a pole line from Altoona to Hazleton, and also a line westward from Pittsburgh to Cleveland by the way of New Castle. There have also been strung ten additional wires on the lines between New York and Philadelphia; and at various points minor additions of wire have been made to meet the growing demands of the business.

"It is the intention, during the course of the current year, to fill the gap between Cleveland, Ohio, and Hammond, Illinois, which last-named place is already connected by the long lines with Chicago; thus giving through service between Boston, New York and Chicago."

And from his March 28, 1893, report:

"The work of connecting together the territories of the different licensees has taken a great step forward. It will be remembered that in the last report the intention was announced of the Long Distance Company of filling the gap between Cleveland, Ohio, and Hammond, Ill., thus giving through service between Boston, New York, and Chicago. This has been done—that Company having added to its construction during the year, 494 miles of pole line, and 8,645 miles of wire, of which 365 miles represent the extension from Cleveland to Chicago, about 74 miles a spur connecting Detroit, by the way of Toledo, with

the through line, and the remainder, some 93 miles, the joint construction and reconstruction upon the Hazleton and Altoona line, in Pennsylvania.

"Of the added mileage of wire, 7,150 miles are strung on the New York-Chicago line; the remainder are wires added to the existing system, chiefly in the New England States and Pennsylvania.

"The general route of the line to Chicago is by the way of Newark, N. J., Harrisburg and Pittsburgh, Pa., Cleveland, and Toledo, Ohio, and South Bend, Ind.

"To determine the feasibility of transmitting speech over the theretofore unapproached distance of one thousand miles—the limit of the successful transmission of speech had not before exceeded 500 miles—a special experimental circuit, consisting of two number-8 hard-drawn copper wires, was constructed. This wire weighs 435 pounds to the mile, and the circuit contains 826,500 pounds of copper. A circuit of the weight generally used for telephone service would weigh less than 200,000 pounds.

"The success was so complete that the lines were at once extended to Boston, and two more circuits ordered strung from New York to Chicago.

"The connecting of these cities together, and the furnishing of apparatus for personal conversation between them, was such an addition to the facilities of business as by sort of common consent to be recognized as a matter of public concern.

"The line from New York to Chicago was formally opened to the public on the 18th of October last, and the line to Boston on the 7th of February, 1893, when his Excellency, Gov. Russell, opened the line by conversation with the company's officers in the office at Chicago. The formal opening in New York was made by his Honor, Mayor Grant, at the company's office in New York, who conversed with his Honor, Mayor Washburne, in Chicago, at the company's office in the last named city.*

"It is now possible from this room or from any properly appointed station on this system, to talk north and east to Augusta, north to Concord, N. H., to Buffalo, N. Y., west to

* On this occasion Alexander Graham Bell in New York conversed with Mr. William H. Hubbard in Chicago. In 1876 Mr. Hubbard had taken charge, for Professor Bell, of the latter's exhibit at the Centennial (*vide* p. 33).

Chicago, and south to Washington, and of course to the principal cities intermediate.

"In the Eastern States connecting lines already reached all important points. As said, a spur has been built to Detroit by way of Toledo. A line had previously been built from Chicago to Milwaukee. Through these branches and through contemplated connecting lines of local companies, all important points in Ohio, Indiana, Illinois, Michigan and Wisconsin as well, will soon be reached.

"It may be interesting to note that within that territory live and do business something more than one-half of the whole population of the United States, so that soon it will not be a figure of speech to say that one-half of the population of the country are within talking distance of each other.

"That this constitutes an addition to the social and business facilities of the country of far-reaching consequence, needs, of course, not to be added. Nor, I suppose, needs it to be said that such a performance taxes to the uttermost the technical resources of the companies in construction and equipment, and in an equal degree their vigilance in inspection and maintenance.

"In building these lines, in building plants to meet the growing business, and in bringing existing plants up to the level of our improved knowledge, and adapting them for use on such an extended scheme, and in yielding to the public demand in the more thickly settled portions of the larger cities that the wires should go underground, in these various branches of the work from 1885 to 1892, principally, however, in the last five or six years of that period, there has been expended, after ample allowance made for repairs and maintenance, no less a sum than \$35,737,049.14.

"This, of course, it will be observed, takes no note of the large investments in the business made prior to 1885."

Continuing, from the report of March 27, 1894, by President Hudson:

"The larger cities to which the lines were extended, and in which service was opened during the year, are Detroit, Cleveland, Cincinnati, Dayton, and Indianapolis. The line from Dayton to Indianapolis forms a link in a proposed through line connecting Pittsburgh and places to the east with St. Louis and the

principal cities en route. The line connecting Detroit, by the way of Toledo and Maumee, with Cincinnati, crosses the above line near Dayton, and reaches directly, and through such connection, a large amount of extra territorial work of the Central Union Company in the States of Ohio and Indiana. The Long Distance lines now reach and connect the exchanges of twenty-six companies licensees.

"The general excellence of the construction of the Long Distance lines is shown by the fact that there were no serious interruptions from storms during the year. . . .

"Large as the expenditures mentioned above have been, the necessity of further capital expenditures for the extension of the business has not yet passed by. Indeed, at the point to which the business has now come, we have to consider, not a series of isolated exchanges or a number of scattered lines, but something very like a national exchange is showing itself.

"The pressure is great to extend the scheme of long lines to the West and to the South. There is of course much to do in the filling up of existing lines, and the local companies will have much to do to meet the extensions of the business. In view of this, as the limit of capital had been reached, your directors have caused application to be made to the Legislature at its present session for authority to increase the capital to fifty millions of dollars.

"The money is wanted, not only to perfect the long lines already built, for which it will be remembered, the last increase was chiefly made, but to develop and extend the system to all paying points throughout the United States as fast as the public demands it. This would involve an outlay of many millions, the whole of which will fall upon this company. The expenditure on long lines alone already amounts to between \$6,000,000 and \$7,000,000.

"The effect of the long lines already has been to work a vast improvement in the local service through the efforts of the local companies to give their subscribers the benefit of the long-distance service. The local plants have largely been changed over into the new order of things, but that work must be completed and provision made for a very large development of business.

"A great outlay will be required for this also, and while the expense will in part be borne by other stockholders in local companies, the American Bell Telephone Company, as a large stockholder in them, must, of course, bear a large part. It should be understood that it is not proposed to issue any part of this stock except as needed for the development of the business."

From the report of March 26, 1895:

"The pole line construction of the Long Distance Company last year consisted mainly of the line from Pittsburgh to Chicago via Indianapolis, and the line between Erie, Pa., and Norwalk, Ohio."

That year and the next witnessed a considerable number of extensions of the Long Lines plant to points in Illinois, Indiana, Ohio, Kentucky, Michigan, Tennessee, and New York.

The final quotation will be from President Hudson's annual report of March 30, 1897, as follows:

"The importance, not only to the business of the companies, but to the general business interests of the country, of this rapid extension of the lines can hardly be overestimated. Isolated exchanges are steadily becoming less in number. The great system of interconnecting lines, linking together the smaller cities and towns, as well as the important commercial centres, has brought many millions of the people within the possibility of speech over long distances by telephone, and the subscriber of to-day, at most of the exchanges, finds himself not only furnished with the facilities for talking with others in the same locality, but able to command, almost on the instant, the service of lines, over which he may, within the time allowed for a toll line connection, hold a conversation of several hundred words with his correspondent at a distant point."

In closing this chapter, let us briefly review the outstanding accomplishments of long-lines service in later years.

In 1911 occurred the extension of the long lines to Denver, Colorado; in 1913 to Salt Lake City, Utah. In 1915 came the opening of commercial transcontinental service between New York and San Francisco. At the present time three transcontinental lines extend

across the United States on northern, central, and southern routes. The year 1921 witnessed the extension of the service to Cuba, utilizing submarine cables of special design across the Straits of Florida, from Key West to Havana. In 1927 it became possible to talk to many points in Mexico. In 1926 the spanning of the Atlantic Ocean by a radio telephone link, employing powerful amplifiers and adapted for connection with the land lines, resulted in commercial service between New York and London. And at the present time, from almost any telephone in the United States, and from many in Canada, Cuba, and Mexico, it is possible to talk with a large proportion of the countries in Western, Northern, and Central Europe and even to North Africa.

This records the progress which has thus far been made in realizing the prophetic vision of world communication by wires "and also by cable and other appropriate means," which the founders expressed in the charter of the American Telephone and Telegraph Company. Much work remains to be done, but no one now doubts that ere long will be achieved the full realization of that amazing prophecy.

APPENDIX A

LIST OF THE MOST IMPORTANT LAW SUITS ARISING OUT OF THE INFRINGEMENT OF ALEXANDER GRAHAM BELL'S TELEPHONE PATENTS, WITH A BRIEF DESCRIPTION OF THE CIRCUMSTANCES OF EACH SUIT

THE DOWD CASE

(Bell Telephone Company et al. *v.* Peter A. Dowd)

ON September 12, 1878, the Bell Telephone Company and one of its licensees, the New England Telephone Company, brought suit in equity in the Circuit Court of the United States for the District of Massachusetts, against Peter A. Dowd, for infringement of the two Bell patents (Nos. 174,465 and 186,787). Dowd was an agent of the Western Union Telegraph Company and its associates, the Gold and Stock Telegraph Company, the American Speaking Telephone Company and the Harmonic Telegraph Company, and was engaged in putting out telephones in the State of Massachusetts.

The Western Union Company defended the suit with great vigor and set up a variety of defenses, among which were the alleged priority of invention of Elisha Gray, Thomas A. Edison, and Amos E. Dolbear; a long list of alleged prior publications, including descriptions of the alleged telephone instruments of Philipp Reis; and the allegation that Bell's instrument, as described in his first patent, was not capable of transmitting articulate speech.

After the evidence had been taken, Mr. George Gifford, counsel for the Western Union Company, became convinced that the Bell patents were valid, and advised a settlement. By the terms of this settlement, which was effected on November 10, 1879, and covered a period of seventeen years, the Western Union Company admitted that Alexander Graham Bell was the inventor of the telephone and that his patents were valid, and agreed to retire from the telephone business. The Bell Company was granted a license under the telephonic inventions that the Western Union Company had acquired or might acquire during the term of the contract, and it agreed to purchase the telephones and telephone exchanges of the Western Union Company and to pay to that company a percentage of its future telephone rentals or royalties.

A final decree, approved by Judge Lowell, was entered by consent on

April 4, 1881. This officially ended the Dowd case, although the record was stipulated into a number of the later infringement suits.

THE EATON AND SPENCER CASES

(American Bell Telephone Company et al. *v.* Ashael K. Eaton et al.)
(American Bell Telephone Company et al. *v.* Albert Spencer et al.)

On June 22, 1880, the American Bell Telephone Company and one of its licensees, the Metropolitan Telephone and Telegraph Company, operating in New York City and its surrounding territory, brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against Ashael K. Eaton, the Eaton Telephone Company and another; and on July 8, 1880, the American Bell Telephone Company and the Bell Telephone Company brought suit in equity in the Circuit Court of the United States for the District of Massachusetts, against Albert Spencer, an agent of the Eaton Telephone Company. Both suits charged that the defendants had infringed the two Bell patents by making and selling magneto receivers and carbon microphone transmitters.

These suits were defended by the Eaton Telephone Company, and the defenses set up embraced the same names of alleged prior inventors and the same list of alleged anticipating prior publications and patents, including descriptions of the alleged telephone instruments of Philipp Reis, put forward in the Dowd case, with several additions; and it was also claimed that the Bell patent, No. 174,465, did not show a skilled person how to construct therefrom a speaking telephone.

The Spencer case was decided by Judge Lowell, who, in his opinion* of June 27, 1881 (8 Federal Reporter 509), adjudged the Bell patents valid and infringed by the defendants' instruments. Judge Lowell's opinion said, in part:

"If the Bell patent were for a mere arrangement, or combination of old devices, to produce a somewhat better result in a known art, then, no doubt, a person who substituted a new element not known at the date of the patent, might escape the charge of infringement. But Bell discovered a new art,—that of transmitting speech by electricity,—and has a right to hold the broadest claim for it which can be permitted in any case; not to the abstract right of sending sounds by telegraph, without any regard to means, but to all means and processes which he has both invented and claimed. The invention is nothing less than the transfer to a wire of electrical vibrations like those which a sound has produced in the air."

Several months after this decision, the suit in New York against Eaton and the Eaton Telephone Company came up for hearing, and as

* A quotation from this opinion will be found on pages 54 and 55 of Chapter IV.

further argument was not desired by the defendants, a final decree was entered against them, on March 25, 1882, by Judge Wheeler.

Neither of these cases was appealed.

THE DRAWBAUGH CASE

(American Bell Telephone Company et al. v. The People's Telephone Company et al.)

On October 20, 1880, the American Bell Telephone Company and the Metropolitan Telephone and Telegraph Company brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against the People's Telephone Company and others, for infringement of the Bell patents. This company, which was organized in August, 1880, had started to put out telephones in New York City.

A preliminary injunction was issued on November 22, 1880.

From February, 1881, to June, 1884, evidence was taken on behalf of the respective parties, involving the testimony of more than 500 witnesses and making a record of over 6,000 printed pages. The principal defense was that Daniel Drawbaugh was the original and first inventor of the telephone and that he had constructed telephonic instruments and used them for the transmission of speech years before Professor Bell or any one else had done so. It was further alleged that the Bell invention was, in fact, made by Elisha Gray, as was shown by Gray's caveat on file in the Patent Office; that the patent was wrongfully issued to Bell; that Thomas A. Edison was a prior inventor of the telephone; and that the instrument described in Bell's patent was not capable of transmitting articulate speech.

On December 1, 1884, Judge Wallace rendered his opinion* (22 Federal Reporter 309), affirming the validity of the Bell patents and adjudging them infringed by the defendants. A decree for a perpetual injunction was issued on December 11, 1884. Subsequently, additional proofs were taken by the defendants and were presented for the consideration of the court. Thereupon, after further argument, Judge Wallace rendered a second opinion, on December 4, 1885 (25 Federal Reporter 725), affirming his former decision.

This case was appealed by the People's Telephone Company to the United States Supreme Court, where it was decided on March 19, 1888. (See under "The Telephone Appeals.")

THE DOLBEAR CASE

(American Bell Telephone Company v. Amos E. Dolbear et al.)

On October 10, 1881, the American Bell Telephone Company brought suit in equity in the Circuit Court of the United States for the District of Massachusetts, against Amos E. Dolbear, Professor of Physics at Tufts

* A quotation from this opinion will be found on page 65 of Chapter IV.

College, and others, for infringement of the Bell patents. Prior to the Dowd case, Professor Dolbear had assigned his telephonic inventions to the Western Union Company, but the apparatus employed by the defendants in this case (a carbon microphone and condenser receiver) was alleged to be covered by a patent applied for by Professor Dolbear on October 11, 1880, and issued on April 5, 1881, subsequent to the Dowd case.

The case first came up for hearing on motion for preliminary injunction. The defense at that time was that the Bell patents must be limited to cover only magneto transmitting and receiving apparatus and were, accordingly, not infringed by the Dolbear instruments. On January 24, 1883, Mr. Justice Gray rendered his opinion * (15 Federal Reporter 448), broadly construing Bell's first patent to cover all known forms of speaking telephones, and adjudging it infringed by the Dolbear apparatus. A preliminary injunction was granted.

On final hearing, in addition to the earlier defense, defendants alleged that Bell's first patent was not sufficient to enable any person to make and use the invention with practical success; that it was an attempt to patent a mere abstraction; and that Bell's invention was anticipated by a long list of prior patents and publications. It was also contended that the Reis instrument could be made to transmit speech, if operated in the manner described by Bell. The experiment attempting to prove the correctness of this contention, made in the presence of counsel, was an utter failure.

On August 25, 1883, Judge Lowell rendered his opinion (17 Federal Reporter 604), adjudging the Bell patents valid and infringed by the defendants' telephones, and granting a perpetual injunction.

This case was appealed to the United States Supreme Court, where it was decided on March 19, 1888. (See under "The Telephone Appeals.")

THE GHEGAN, ALBRIGHT, AND HOPKINS CASES

(American Bell Telephone Company et al. v. John J. Ghegan.)

(American Bell Telephone Company v. Andrew Albright.)

(American Bell Telephone Company et al. v. The People's Telephone and Telegraph Company et al.)

On May 26, 1882, the American Bell Telephone Company and two of its licensees, the Metropolitan Telephone and Telegraph Company and the Domestic Telephone Company, brought suit in equity in the Circuit Court of the United States for the District of New Jersey, against John J. Ghegan, for infringement of the Bell patents. Ghegan had put out a number of telephones and had announced that he would start an exchange in Newark. He was a licensee of the People's Telephone and Telegraph Company, a New York corporation, and the suit was defended by that company. The defenses embraced the same list of alleged prior inventors

* A quotation from this opinion will be found on page 68 of Chapter IV.

and anticipating publications and patents set up in previous cases, with a few additions, principally the claims of James W. McDonough, upon whose alleged priority of invention considerable stress was laid. On November 18, 1882, a preliminary injunction was granted by Judge Nixon, and on March 31, 1883, further defense having been abandoned, a final decree was entered by Judge McKennan, adjudging the Bell patents to be valid and infringed by the defendant.

On June 8, 1882, the American Bell Telephone Company brought suit in equity in the same court against Andrew Albright, a manufacturer in Newark, who had furnished the capital for Ghegan's enterprise and who had also built a telephone line between his house and factory in Newark. After the answer had been filed, this case was continued to await the result of the motion for preliminary injunction in the Ghegan case, and after that, on final hearing, further defense was abandoned, and on March 23, 1883, a decree for injunction and account was entered. As the result of accounting proceedings before a Master, on September 30, 1887 Judge Bradley rendered an opinion (32 Federal Reporter 287), entering a final decree against the defendant.

On February 6, 1883, the American Bell Telephone Company and the Metropolitan Telephone and Telegraph Company brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against the People's Telephone and Telegraph Company, and others, for infringement of the Bell patents. This suit is for convenience referred to as the Hopkins case, to distinguish it from the two cases noted above, also involving the People's Telephone and Telegraph Company. In all three cases, the defendants used a so-called "mercury-float" transmitter patented by George M. Hopkins. On March 30, 1883, a preliminary injunction was granted by Judge Wallace. On final hearing, elaborate defenses were presented and much additional evidence that had been taken in the meantime in other suits (the Molecular and Overland cases) was introduced by stipulation. On December 7, 1885, a final decree was entered by Judge Wallace, affirming the validity of the Bell patents and adjudging them infringed by defendants.

None of these three cases was appealed.

THE OVERLAND CASES

- (American Bell Telephone Company et al. *v.* The Overland Telephone Company et al.)
- (American Bell Telephone Company *v.* The Overland Telephone Company of New Jersey et al.)
- (American Bell Telephone Company *v.* The Penn Overland Telephone and Telegraph Company et al.)
- (American Bell Telephone Company et al. *v.* The Baxter Overland Telephone and Telegraph Company of Central New York et al.)
- (American Bell Telephone Company et al. *v.* The Overland Telephone Company of Lexington, Ky., et al.)

These suits involved the Overland Telephone Company, a New York corporation, and a number of subsidiary Overland companies organized to operate throughout the United States, of which the companies listed above were perhaps the most active. Each company used transmitters and receivers embodying alleged improvements based upon the patents of Dr. M. L. Baxter, and each suit for infringement of the Bell patents was defended by the parent Overland Company.

On April 12, 1883, the American Bell Telephone Company and the Metropolitan Telephone and Telegraph Company brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against the Overland Telephone Company and others. The defenses set up were the same as had been put forward in the Ghegan case. On final hearing, all the evidence which had been taken in the Molecular and Drawbaugh cases was introduced. On December 7, 1885, Judge Wallace entered a final decree, adjudging the Bell patents to have been infringed and ordering a perpetual injunction to issue.

On October 17, 1883, the American Bell Telephone Company brought suit in equity in the Circuit Court of the United States for the District of New Jersey, against the Overland Telephone Company of New Jersey and others; and another suit was brought, on October 27, 1883, in the Circuit Court of the United States for the Eastern District of Pennsylvania, against the Penn Overland Telephone and Telegraph Company and others. In both cases the defenses included those that had been set up in the Dowd, Spencer, Drawbaugh, Dolbear, and Ghegan cases. A decree for preliminary injunction was entered against the Penn Overland Company on January 13, 1885, by Judge Butler, and against the Overland Company of New Jersey on January 16, 1885, by Judge Nixon. Final decrees, adjudging the Bell patents to have been infringed, were entered on December 23, 1885, against the New Jersey Overland Company, and on January 5, 1886, against the Penn Overland Company.

On October 4, 1884, the American Bell Telephone Company and one of its licensees, the Central New York Telephone and Telegraph Company, brought suit in equity in the Circuit Court of the United States for the Northern District of New York, against the Baxter Overland Telephone and Telegraph Company of Central New York and others, who had established a large exchange at Utica. On March 17, 1885, a preliminary injunction was granted by Judge Wallace, and a final decree was entered on March 27, 1886, by Judge Coxe.

On August 31, 1885, the American Bell Telephone Company and one of its licensees, the East Tennessee Telephone Company, brought suit in equity in the Circuit Court of the United States for the District of Kentucky, against the Overland Telephone Company of Lexington, Kentucky, and others, who had built an exchange in Lexington. A preliminary injunction was granted by Judge Barr, on October 8, 1885, and a final decree was entered on January 8, 1886.

The main Overland case (*American Bell Telephone Company et al. v. The Overland Telephone Company et al.*), was appealed to the United States Supreme Court, where it was decided on March 19, 1888. (See under "The Telephone Appeals.")

THE MOLECULAR CASES

(*American Bell Telephone Company et al. v. The Molecular Telephone Company et al.*)

(*American Bell Telephone Company et al. v. The Citizens' Telegraph and Telephone Company et al.*)

On July 17, 1883, the American Bell Telephone Company and the Metropolitan Telephone and Telegraph Company brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against the Molecular Telephone Company and others, for infringement of the Bell patents. In the trial of this case, the Molecular Company introduced a large amount of evidence, the defenses including additional publications relating to the work of Philipp Reis; testimony in support of the claims of Alfred G. Holcomb and Philip H. Van der Weyde, as alleged prior inventors of the electric speaking telephone; all of the testimony submitted in the Dowd case in support of the claims of Elisha Gray; and much expert testimony to the effect that the Reis apparatus was a true speaking telephone, that the instruments described in Bell's patent No. 174,465 would not talk, and that the defendants' carbon microphone transmitter did not embody the invention claimed in the Bell patent. The evidence of both parties filled more than 1,500 printed pages.

On June 24, 1885, Judge Wallace rendered his opinion (32 Federal Reporter 214), affirming the validity of the Bell patents and adjudging them infringed, and ordering a perpetual injunction to issue. Following is a quotation from Judge Wallace's opinion:

"The argument of counsel has been addressed to the question of priority as between Bell and one Holcomb, and as between Bell and one Beardslee, who is not named in the answer as a prior inventor.

"Holcomb asserts that he made his invention in 1860. His theory is, that in the winter of 1859-60 he invented a polarized electromagnet, which was an extremely sensitive one, and was capable of receiving articulate speech, and was patented by him in May, 1860; that, about the time of procuring that patent, he conceived the idea of converting the force of the human voice into electricity; that, early in the fall of 1860, he constructed a telephone consisting of one of his polarized magnets, a wooden diaphragm mounted on a box or mouth-piece, and a U-shaped soft iron armature attached to the

diaphragm, extending towards and in proximity to the ends of the polar extension of the magnet, but not touching them, the diaphragm box and magnet being secured to and held in their relative positions by a base common to both. He states that soon after completing this instrument, he made a duplicate of it, and connected the helices of both the magnets in a complete or closed electrical circuit; that, while listening at one of the instruments, he was able to hear and recognize articulate words spoken into the mouth-piece of the other instrument by other persons, and that he used those instruments on several occasions and showed them to several persons. He states that his telephone then embodied all the essential features of the present telephone.

"He did not file an application for a patent until January, 1878. The instruments which he says he constructed are not produced, but all the parts are lost except a permanent steel magnet, a sounding-box, a steel bow with a brass attachment, a brass clamp, and some broken pieces of the diaphragm. No witness is produced in corroboration of Holcomb, who heard the instrument(s) used, except Holcomb's wife, or who were present when they were used. Several witnesses are produced, however, men of intelligence, who were interested in Holcomb's electrical mechanism, and were more or less familiar with what he had accomplished, but none of them seemed to be aware that he claimed to have succeeded in transmitting speech by the apparatus which he had made. In June, 1861, he obtained a patent for other electrical mechanisms. From 1862 or 1863 to 1875 he does not seem to have made any efforts to perfect his telephone mechanism, and it was not until Bell's invention had attracted general public interest that he resumed his efforts to perfect it. During this period he was so indifferent to the importance of what he had accomplished that he suffered the instruments which he had made to be lost. He was not in indigent circumstances, and it appears that he bought a farm in Maryland in 1862. He was fully competent to appreciate the great merit and value of his invention, if he had actually succeeded in transmitting speech with his mechanism. He does not vouchsafe any explanation why, for a period of fifteen years, he permitted his invention to lie dormant. The presumption of priority and validity arising from the grant of letters patent cannot be overthrown by a case like this; it suggests too many improbabilities to merit serious consideration.

"In August, 1878, a suit was brought by the present complainants against the Western Union Telegraph Company, for infringement of the patent in suit. Mr. Pope was then the electrician of that company, and was aware that Holcomb had made an application for a patent. The company set up the priority of Holcomb among other defenses, in that suit. Mr. Pope investigated Holcomb's pretensions, and had an interview with him in reference to the defense

of the suit. He questioned Holcomb, to ascertain whether he could produce any witnesses to substantiate his statement that he had transmitted articulate speech by means of his apparatus. Holcomb could tell him of no living witnesses. As a result of this interview, Mr. Pope concluded that it was not advisable for the Western Union Telegraph Company to purchase Holcomb's rights, and Holcomb was not called as a witness to substantiate the defense. The impression produced upon Mr. Pope was such as would be derived by any sensible man by an investigation of the facts and circumstances.

"For the purpose of corroborating Holcomb, the defense produced Mr. Beardslee as a witness. He testified that Dr. Bradley, an acquaintance of his, brought Holcomb to see him, and he described an instrument which Holcomb exhibited to him on that occasion, which he thinks was some time in 1861 or 1862. He testified that Holcomb claimed that, by the use of such instruments, he could communicate sounds and words at a distance, through an electric current. Upon the cross-examination of this witness, he testified that he himself made, immediately after that interview, several organizations, to test for his own satisfaction the correctness of Holcomb's assertions about his instrument. He said the instruments thus made demonstrated that the human voice could be conveyed by the means pointed out by Holcomb, but he saw nothing to indicate that they would operate at great distances, and he never took any further interest in them, but regarded them as a mere toy. "Upon this testimony, it is urged, for the defendants, that the Beardslee instruments defeat the novelty of the patent. It suffices, without further remark, to say of this defense, that the instruments are not produced, and were never publicly used, and that the witness, who is a mechanical engineer, fully qualified to appreciate their merits, never regarded them as of any practical value."

On July 25, 1885, the American Bell Telephone Company and one of its licensees brought suit in equity in the Circuit Court of the United States for the Northern District of Ohio, against the Citizens' Telegraph and Telephone Company, a subsidiary of the Molecular Telephone Company, which had opened an exchange in Cleveland. At a hearing before the Honorable Stanley Matthews, Associate Justice of the Supreme Court, and the Honorable Martin Welker, District Judge, held on August 18, 1885, a preliminary injunction was granted.

The Molecular case was appealed to the United States Supreme Court, where it was decided on March 19, 1888. (See under "The Telephone Appeals.")

THE CLAY CASE

(American Bell Telephone Company et al. v. The Clay Commercial Telephone Company et al.)

On April 24, 1884, the American Bell Telephone Company and one of its licensees, the Bell Telephone Company of Philadelphia, brought suit in equity in the Circuit Court of the United States for the Eastern District of Pennsylvania, against the Clay Commercial Telephone Company and others—who had established a telephone exchange in the city of Philadelphia—for infringement of the Bell patents. In their answer, defendants set up all that had been filed in the answers of the New Jersey and Penn Overland Companies, the amended answer of the Molecular Company, and several additional alleged prior publications and patents. A restraining order was entered on April 24, 1885.

On final hearing the defenses relied upon were, among others, that the apparatus described in patent No. 174,465 had never talked and could not talk; that if Bell ever invented the electric speaking telephone, he did it after his patent had issued; that the invention had been anticipated by Philipp Reis; and that the microphone transmitter and magneto receiver employed by defendants did not produce an undulatory current, as described by Bell, but an intermittent current. The legality of Bell's second patent was also attacked.

On March 20, 1886, defendants filed a petition that the restraining order be vacated and that the case be continued to await the result of a suit in equity which was then about to be instituted in the name of the United States for the purpose of procuring the annulment of the Bell patents. At a hearing, on April 5, 1886, before Judges McKennan and Butler, this petition was dismissed, and on April 12, 1886, a final decree was entered affirming the validity of the Bell patents and adjudging them infringed by the defendants.

This case was appealed to the United States Supreme Court, where it was decided on March 19, 1888. (See under "The Telephone Appeals.")

THE McDONOUGH CASE

(American Bell Telephone Company et al. v. The McDonough Telephone and Telegraph Company et al.)

On November 6, 1884, the American Bell Telephone Company and the Metropolitan Telephone and Telegraph Company brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against the McDonough Telephone and Telegraph Company and others, for infringement of the Bell patents. Among these defendants was James W. McDonough, who had been named in the answers of the

defendants in the Ghegan, Hopkins, Overland, Molecular, and Clay cases, as a prior inventor of the speaking telephone.

McDonough had applied for a patent, on April 10, 1876, for a peculiar form of telephone instrument about a foot in diameter, and resembling a small tambourine. This instrument, which was called a "teleloge," had been placed in interference in the Patent Office with Bell's patent No. 174,465 and with applications of other persons. The decision in the Patent Office was that McDonough had only reproduced in substance the old circuit-breaking apparatus of Reis, and no patent was issued to him on his application of April 10, 1876.

The principal defense set up by defendants was the priority of invention of the electric speaking telephone by Reis and McDonough. On February 14, 1885, Judge Wallace granted a preliminary injunction, and on June 5, 1886, he entered a decree affirming the validity of the Bell patents, adjudging them infringed by defendants, and ordering a perpetual injunction.

This case was not appealed.

THE PAN ELECTRIC CASES

- (American Bell Telephone Company et al. v. The Pan Electric Telephone Company, the Rogers Telegraph and Telephone Company, et al.)
- (American Bell Telephone Company et al. v. The Pan Electric Telephone Company, the Washington Telephone Company, et al.)
- (American Bell Telephone Company et al. v. The Texas Pan Electric Telephone Company et al.)
- (American Bell Telephone Company et al. v. The Dallas Pan Electric Telephone Company et al.)
- (American Bell Telephone Company et al. v. The Denison Pan Electric Telephone Company et al.)
- (American Bell Telephone Company et al. v. The Abilene Telephone Company et al.)

These suits involved the Pan Electric Telephone Company, a Tennessee corporation, and a number of subsidiary companies organized to operate in the states of Pennsylvania, Maryland, and Texas, under certain patents issued to J. Harris Rogers for alleged improvements in electric speaking telephones.

On November 13, 1884, the American Bell Telephone Company and one of its licensees, the Pennsylvania Telephone Company, brought suit in equity in the Circuit Court of the United States for the Eastern District of Pennsylvania, against the Pan Electric Telephone Company, the Rogers Telegraph and Telephone Company, and others, for infringement of the Bell patents. This suit was not defended by the Pan Electric Telephone Company, and on June 26, 1885, a final decree was issued by Judge Butler,

granting a perpetual injunction against the Rogers Telegraph and Telephone Company (the operating company in Pennsylvania).

On July 16, 1885, the American Bell Telephone Company and one of its licensees, the Chesapeake and Potomac Telephone Company, brought suit in equity in the Circuit Court of the United States for the District of Maryland, against the Pan Electric Telephone Company, the Washington Telephone Company, and others, for infringement of the Bell patents. In answer, defendants set up the same defenses which were filed in the amended answer of the Molecular Telephone Company. On July 19, 1886, Judge Bond granted a preliminary injunction against the Washington Telephone Company (the operating company in Maryland), and on April 12, 1888, a final decree was entered by Judge Morris granting a perpetual injunction.

On June 28, 1886, the American Bell Telephone Company and one of its licensees, the Southwestern Telegraph and Telephone Company, brought suit in equity in the Circuit Court of the United States for the Northern District of Texas, against the Texas Pan Electric Telephone Company and others, for infringement of the Bell patents; and at the same time and place suits were brought against the Dallas Pan Electric Company, the Denison Pan Electric Company, and the Abilene Telephone Company, subsidiary companies of the Texas Pan Electric Company. These suits were not defended by the parent Pan Electric Telephone Company, and preliminary injunctions against all four companies were granted by Judge Pardee on November 5, 1886.

None of these cases was appealed.

THE LOUISIANA NATIONAL IMPROVED TELEPHONE COMPANY, CRESCENT CITY, AND WESTERN PENNSYLVANIA CASES

(American Bell Telephone Company et al. *v.* The National Improved Telephone Company, Crescent City Telephone Company, et al.)

(American Bell Telephone Company et al. *v.* The Western Pennsylvania Telephone Company et al.)

These suits involved the National Improved Telephone Company, a Louisiana corporation, and two subsidiary companies, the Crescent City Telephone Company and the Western Pennsylvania Telephone Company, operating in New Orleans, La., and Pittsburgh, Pa., respectively, and using telephones furnished by the parent company and purported to be founded upon certain minor patents issued to J. Harris Rogers and C. A. Randall.

On March 23, 1885, the American Bell Telephone Company and one of its licensees, the Central District and Printing Telegraph Company, brought suit in equity in the Circuit Court of the United States for the Western District of Pennsylvania, against the Western Pennsylvania Telephone Company and others, for infringement of the Bell patents. A preliminary injunction was granted by Judges McKennan and Acheson on

July 8, 1885. On final hearing, defendants introduced all of the evidence taken and put in by stipulation in the Overland, New Jersey Overland, and Penn Overland cases. On December 24, 1885, a final decree was entered by the same judges, adjudging the Bell patents to have been infringed and granting a perpetual injunction.

On November 5, 1885, the American Bell Telephone Company and one of its licensees, the Great Southern Telephone Company, brought suit in equity in the Circuit Court of the United States for the Eastern District of Louisiana, against the National Improved Telephone Company, the Crescent City Telephone Company, and others, for infringement of the Bell patents. The Crescent City Telephone Company was the operating company, and had started an exchange in New Orleans. The principal defenses relied upon in this case were: that after the filing of Bell's application his specifications and claim were changed as the result of information surreptitiously obtained from Gray's caveat; that the Bell apparatus, as described in the patent specification, was not capable of transmitting articulate speech; and that Bell's invention was anticipated by Philipp Reis. On May 31, 1886, Judges Pardee and Billings rendered an opinion (27 Federal Reporter 663), affirming the validity of the Bell patents and adjudging them to have been infringed by defendants. A decree for a preliminary injunction was entered on the same day, and a final decree, granting a perpetual injunction, was entered by Judge Pardee on April 27, 1888.

None of these cases was appealed.

THE GLOBE CASE

(American Bell Telephone Company et al. v. The Globe Telephone Company et al.)

The Globe Telephone Company was incorporated in New York in April, 1883, ostensibly on the minor telephone patents of George E. Shaw, but in reality its sole assets were the pretensions of Antonio Meucci to the original invention of the telephone. In September, 1885, the Globe Company issued a circular setting forth that it had secured Meucci's title to the invention of the electric speaking telephone and had procured instruments which were not infringements of the Bell patents, and inviting the public to purchase these instruments. Early in the year 1886, S. R. Beckwith, the General Manager of the Globe Company, organized the Meucci Telephone Company in New Jersey, for the purpose of erecting a telephone exchange in Elizabeth. Meucci was the nominal electrician of this company.

On November 10, 1885, the American Bell Telephone Company and the Metropolitan Telephone and Telegraph Company brought suit in equity in the Circuit Court of the United States for the Southern District of New York, against the Globe Telephone Company, Beckwith, Meucci, and others, for infringement of the Bell patents.

On July 19, 1887, Judge Wallace rendered an opinion * (31 Federal Reporter 729), dismissing the pretensions of Meucci to the invention of the telephone, and adjudging the Bell patents to have been infringed by the defendants. A final decree, granting a perpetual injunction, was entered on July 30, 1887.

An appeal was taken in this case, but was not perfected.

THE CUSHMAN CASES

(American Bell Telephone Company et al. v. The American Cushman Telephone Company et al.)

(American Bell Telephone Company et al. v. The Cushman Telephone and Service Company et al.)

The Cushman cases involved the American Cushman Telephone Company and various subsidiary companies, the most prominent of which was the Cushman Telephone and Service Company, which established exchanges at South Bend, Laporte, and Elkhart, Indiana. All of the subsidiary companies used telephones manufactured and furnished by the American Cushman Telephone Company.

On July 20, 1886, the American Bell Telephone Company and one of its licensees, the Chicago Telephone Company, brought suit in equity in the Circuit Court of the United States for the Northern District of Illinois, against the American Cushman Telephone Company and others, for infringement of the Bell patents. Trial of the case was deferred pending the decision of the United States Supreme Court in the Telephone Appeals. After the Supreme Court decision, the case came on for final hearing. Defendants based their defense solely upon the allegation that the electric speaking telephone was not invented by Bell, but by Dr. S. D. Cushman, who, it was further alleged, had constructed and used an electromagnetic telephone at Racine, Wisconsin, as early as 1851.

On July 21, 1888, Judge Blodgett rendered his opinion (35 Federal Reporter 734), adjudging the Bell patents to have been infringed and granting a perpetual injunction. The following language is quoted from Judge Blodgett's opinion:

"Cushman . . . is now about seventy years old. In his early manhood he studied, and afterwards for a short time practiced, medicine; but in 1848, or about that time, he became interested in telegraphy, and abandoned his profession, and has since followed the occupations of telegraph operator, constructor of telegraph lines, manufacturer of lightning-rods, and manufacturer and patentee of divers devices, mainly, if not all, pertaining to the application and control of the electric current.

"His own account of the alleged invention of the telephone by him-

* A quotation from this opinion will be found on page 56 of Chapter IV.

self is that, in the spring of 1851, he was engaged in constructing a telegraph line from Racine westward to Beloit and other towns, and his attention had also been attracted to a device called a 'lightning arrester,' intended to prevent the atmospheric electricity from passing over the telegraph wires and injuring the relay wires and other working apparatus of the telegraph office; and in order to indicate the presence of atmospheric electricity upon the wires of the telegraph line, and thereby test the value and efficiency of this 'lightning arrester,' he constructed an apparatus consisting of an electric horseshoe magnet, with a permanent magnet placed between the legs, and connected at the bend with the electromagnet; and these magnets, so arranged with relation to each other, were placed in a wooden box, with the wires leading outwardly from the electric coils, and with the open ends of the magnets extending upward; and to the under side of the cover of the box, directly over the ends of the magnets, was attached a thin piece of sheet-iron, so located that when the magnets were heavily charged with the electric current this sheet-iron plate would be drawn down in contact with the end of the permanent magnet, and there held until released by hand. Two boxes or sets of this apparatus were made, one of which was placed under a bridge in a swamp some distance west of Racine, one of the wires from the magnets being connected with the telegraph wire passing the vicinity of the bridge, with the other wire serving as a ground wire, and the other box was placed in the office of the telegraph company in Racine, and one wire from the magnets connected with the telegraph wire in the office, and the other with the ground. And soon after these magnet boxes were so placed, he discovered that he could hear in the office the peeping of frogs, or sounds like the peeping of frogs, in the swamp; and after the discovery of this fact, experiment, as he says, showed that the sounds of rapping on the lid of the box in the swamp could be heard in the office, or rapping upon the lid of the box in the office could be heard at the box in the swamp, so that messages or communications could be interchanged between the two boxes by rapping, so as to indicate the Morse alphabet; and, as is claimed, some further experiments resulted in transmitting articulate words from one box to the other. He also states that, soon after the discovery of these phenomena, he, with the assistance of his brother, W. P. Cushman, and one B. T. Blodgett, constructed four boxes substantially like those he had used to test the lightning arresters on the telegraph line; . . . With these boxes, he says, they . . . made experiments upon the telegraph wires on the line west of Racine, and succeeded in obtaining the transmission of articulate speech so as to be understood for a distance of from half a mile to three miles. . . .

"It is further claimed that in the summer of 1853 W. P. Cushman

lived on a farm about six miles west of Racine, and Blodgett had a shop in some part of the city of Racine, and as a telegraph line from Racine passed close to W. P. Cushman's house, one of these 'talking boxes,' as they were called, was placed in one of the rooms of Dr. Cushman's house and another in Blodgett's shop, and a third in a building near the dwelling-house of Cushman on his farm, and these boxes were connected with the wire of the telegraph line, and . . . were used . . . to talk . . .

" . . . Dr. Cushman . . . must have had some of that sanguine temperament and imaginative mind which characterizes the inventor ; and his career . . . shows him to have been a sagacious and in many respects capable business man, and I can hardly conceive it possible that, if he had succeeded in sending articulate speech for a distance of six miles by his device, so as to utilize it for errands and social purposes, he would not have realized that it was even then, in its then state of development, of sufficient value to be covered by a patent, as he was then doing with his other inventions. . . . his imagination, made perhaps morbidly active by seeing how much of fame and profit he had missed, has clothed what he did in those past years with a light reflected from the success of others, and his statements of what he did then have unconsciously colored the testimony of many of those he has called to support him. . . .

"I do not think the testimony, when fairly considered, shows that Dr. Cushman produced at Racine or elsewhere, prior to the invention of Bell, a practical operative telephone of any kind. He gave the world nothing. What he did, if he did anything but make an acoustic telephone, was suffered to die in the embryo or germ before any valuable or useful fruition.

"I do not, from the proof, believe that the machines made by him during these experimental years were so far perfected as to be of any practical value, or to even suggest that they might be so improved as to become valuable and useful. . . . When the Bell telephone was brought to the attention of the public, its value and possible utilities were grasped at once. It was accepted as a great invention, by the general public, as soon as its operation was seen ; and I can see no reason why the public would not as readily have comprehended its advantages and value in 1851, as in 1876, had the machine been so far developed as to give substantial promise of what Bell accomplished."

On July 21, 1888, the American Bell Telephone Company and one of its licensees, the Central Union Telephone Company, brought suit in equity in the Circuit Court of the United States for the Northern District of Illinois, against the Cushman Telephone and Service Company and others, for infringement of the Bell patents. No defense was made, and on October 29, 1888, Judge Blodgett rendered an opinion (36 Federal Re-

porter 488), adjudging the Bell patents to have been infringed and granting a preliminary injunction. On July 24, 1889, a final decree was entered.

None of the Cushman cases was appealed.

THE SOUTHERN TELEPHONE COMPANY CASE

(American Bell Telephone Company et al. *v.* The Southern Telephone Company et al.)

This was the last of the more important infringement suits brought on the Bell patents and is sometimes referred to as the Little Rock Case. The Southern Telephone Company was a Pan Electric subsidiary which had established an exchange at Little Rock, Arkansas.

On October 14, 1887, the American Bell Telephone Company and the Southwestern Telegraph and Telephone Company brought suit in equity in the Circuit Court of the United States for the Eastern District of Arkansas, against the Southern Telephone Company and others, for infringement of the Bell patents. The case came on for hearing in April, 1888, and although the opinion of the United States Supreme Court in the Telephone Appeals had then been promulgated, defendants' counsel argued the case at length, asserting that the defendants' instruments operated on the make-and-break principle, and hence did not infringe; and that the Bell Company had been guilty of laches in bringing suit.

On April 21, 1888, Judge Brewer rendered his opinion (34 Federal Reporter 795), adjudging the Bell patents to have been infringed and ordering a preliminary injunction to issue. On November 1, 1888, a final decree was entered, granting a perpetual injunction.

This case was not appealed.

THE TELEPHONE APPEALS

(Amos E. Dolbear et al. *v.* The American Bell Telephone Company.)

(Molecular Telephone Company et al. *v.* The American Bell Telephone Company et al.)

(American Bell Telephone Company et al. *v.* The Molecular Telephone Company et al.)

(Clay Commercial Telephone Company et al. *v.* The American Bell Telephone Company et al.)

(People's Telephone Company et al. *v.* The American Bell Telephone Company et al.)

(Overland Telephone Company et al. *v.* The American Bell Telephone Company et al.)

These were appeals to the United States Supreme Court in five of the cases already described. In the Molecular case, a cross appeal was filed

by the American Bell Company, due to the adverse decision of the Circuit Court on the fifth claim of Bell's second patent.

The cases came on for hearing in January and February, 1887, at which time no less than twelve days were devoted to oral argument by the various counsel. Practically all of the defenses heretofore noted were employed. All of the respondents denied that Bell was the original inventor of the telephone and that his patents were valid, and all contested the scope that had been given by the courts below to the fifth claim of his first patent. Long lists of what were claimed to be anticipatory prior publications were set forth, and the names of fifteen alleged prior inventors of the telephone were brought forward, chief reliance being placed upon the claims of Reis, Gray, Drawbaugh, McDonough, and Van der Weyde.

The cases were decided on March 19, 1888 (126 U. S.), by a divided court. The majority opinion,* written by Mr. Chief Justice Waite, reviewed at length all of the contentions of the respondents and held that Bell was the original inventor of the telephone, that his patents were valid, and had been infringed by the respondents. The decisions of the lower courts, in so far as they favored the Bell Company, were in each case affirmed, and the decision in the Molecular case, in so far as it disallowed the fifth claim of Bell's second patent, was reversed and decided in favor of the Bell Company.

Mr. Justice Bradley wrote a dissenting opinion, concurred in by two of his associates, expressing his conviction that Daniel Drawbaugh had anticipated Bell in the invention of the electric speaking telephone.

* Quotations from this opinion will be found on pages 55, 61, and 68 of Chapter IV.

APPENDIX B

EARLY USES OF THE WORD "TELEPHONE"

FOR many years before Bell made his invention, the word "telephone," in one form or another, had been used to designate different devices for conveying intelligence to a distance. This appendix contains information as to these early uses of the word, with some description of the apparatus to which it was applied.

In striving to trace the use of the word "telephone" to its beginnings, recourse has been had to several sources of information, including the *Oxford Dictionary*,* the annals of scientific societies, numerous articles in technical magazines of the nineteenth century, and books dealing with various phases of the early history of the communication art. Extracts from these sources are given below in chronological order.

1.—This reference concerns the use of the word "telephone" in the year 1796.

Dr. Fritz Ulmer published, in the *Archives for the History of Natural Sciences and Engineering*,¹ in 1910, an article entitled, "The First Telephone—a Speaking-Tube from the Year 1796."² The text of his article indicates that the name "speaking-tube" was applied to what is commonly called a speaking-trumpet, or megaphone. At the beginning of the article, Dr. Ulmer refers to a paper by R. Hennig, "Development of Telegraphy and Telephony,"³ which mentions the early uses of the word "telephone" by Doctor Romershausen, Sudre, and Wheatstone (which will be taken up in the following pages), and continues:

"To this paragraph we add the following lines which are to prove, as mentioned before, that the words 'Telephon' and 'Fernsprecher' are forty years older than indicated by Hennig; that they were used at the end of the eighteenth century, with a practically modern interpretation, for example, by a German student Huth, in a tiny volume⁴: 'G. Huth, J. H. Lambert's treatise concerning some acoustic instruments. Translated from the French with an appendix

* The *Oxford Dictionary*—a work of profound scholarship—contains the most comprehensive list of references anywhere to be found. Most of the devices described in the following pages are referred to in it. Any one desiring to pursue the uses of the words "telephone," "telephony," and "telephonic" further should consult the *Oxford Dictionary*.

¹ *Archiv für die Geschichte der Naturwissenschaften und der Technik*, vol. 3, 1910, p. 256-262.

² *Das erste Telephon—ein Sprachrohrtelegraph aus dem Jahre 1796*.

³ *Die Entwicklung der Telegraphie und Telephonie*, Leipzig, 1908.

⁴ Located in the city library of Hamburg.

on the so-called horn of Alexander the Great, on experiences with an elliptical speaking-tube and on the utilization of the speaking-tube in telegraphy. With two copper plates. Berlin 1796.' "⁵

With reference to Huth's book, Dr. Ulmer says that it seems to have never been heard of in other libraries, since not even Darmstadter's *Handbook of History of Natural Science and Engineering* gives his name and work. According to Dr. Ulmer, Huth, in the third appendix: "Concerning the application of the speaking-tube to telegraphy," selects as his starting point the great discovery of his time, the transmission of optical signals (semaphore) by Chappe. Huth realizes fully the advantages and success of Chappe's method in the short time of its existence. However, its disadvantages, the excessive cost of operation, because of the required spy-glass, and the shortcomings which it has in common, due to its very nature, with all telegraphs using visible signs for the conveying of messages (namely, that in thick weather it becomes useless and cannot be used even on a clear night without an excessive increase in cost), lead him to search for a substitute. This he found in the speaking-tube, or mouth trumpet. He proposed to install trumpets (megaphones) in stations separated as far as their action would permit, the instruments to be so constructed that they could be moved with ease in all directions. In these stations he recommended that there should be two men, able to speak loudly and clearly, who would relieve each other, each serving a certain number of hours during which he would always be standing or sitting before the speaking-tube. He was to listen carefully to whatever was told him or repeated to him, and repeat it immediately into his tube to the next station. In this manner, said Huth, the message is dictated from one point to the other like wild-fire.

Dr. Ulmer, after observing that this type of telegraphy differed from that previously employed, in that it was acoustic instead of optical, quotes Huth as follows: "this distinct difference (p. 109) might deserve a different name and it might become necessary to give a different name to telegraphic communication by means of speaking-tubes. What would be more appropriate here than the word derived also from the Greek: Telephone or Fernsprecher?" "⁶

⁵ Demgegenüber sollen die folgenden Zeilen, wie schon erwähnt, den kurzen Nachweis führen, dass die Worte „Telephon“ und „Fernsprecher“ schon 40 Jahre älter sind; dass sie schon Ende des 18. Jahrhunderts in einer fast modernen Bedeutung gebraucht wurden, und zwar von einem deutschen Gelehrten Huth, dessen Büchlein*: „G. Huth, J. H. Lamberts Abhandlung über einige akustische Instrumente. Aus dem Französischen übersetzt nebst Zusätzen über das so genannte Horn Alexanders des Grossen, über Erfahrungen mit einem ellipt. Sprachrohr und über die Anwendung der Sprachröhre zur Telegraphie. Mit 2 Kupfertaf. Berlin 1796.“

* Vorhanden in der Hamburger Stadtbibliothek.

⁶ „dieser wesentliche Unterschied (S. 109!) also wohl einen verschiedenen Namen für die telegraphische Anstalt mittelst der Sprach-Röhre verdienen und gewissermassen nothwendig machen. Welcher aber würde nun hier sich schicklich empfehlen, als der gleichfalls aus dem Griechischen entlehnte: Telephon, oder Fernsprecher?“

In further quotations made by Dr. Ulmer from Huth's book, the word "Telephon" occurs repeatedly. These instances are the first that have been found of the use of the word.

Before passing on to subsequent uses, a further quotation from Huth will be given as it contains matter of considerable interest. The original text may be found in Dr. Ulmer's paper.

"Since the speaking-tube amplifies the human voice and increases its range of audibility, it is possible to add some minor aims after the major one for which the telephone is constructed has been attained; namely, that it serves as a general herald throughout the land by proclaiming all public announcements to the individual stations and the surrounding territory; under this heading we can include announcements of commands from authorities, auctions, sales and leasing of land, large robberies, etc. All such communications of public interest, now broadcast through handbills or street-criers, would be spread abroad more quickly by means of the telephone. In this manner, this institution would increase not only in utility but would earn a considerable portion of its upkeep costs, an advantage which would be increased still further by permitting private individuals to rent these facilities; it would enable them to convey urgent messages to friends and relatives, a privilege which would be indulged in frequently by the rich and which would be a desirable asset to the merchant."

Huth also expressed the hope that practical tests would succeed "in making the speaking-tube a useful tool of service to the public, that it will be perfected for that purpose and that it will become an active communication medium of human thoughts and thus an instrument for the easier and quicker dissemination of human culture,"—a hope which Bell's invention was destined to fulfill nearly a century later.

2.—In 1835 there appeared in the *Mechanics' Magazine*, an English publication, an article entitled "The Telephony, or Musical Telegraph," from which the following extracts are taken:*

"In January, 1828, a M. Sudre presented to the French Academy of Fine Arts the scheme of an universal language, formed of the seven musical signs, *re, mi, fa, sol, la, si, do*, variously combined, to which he, therefore, gave the name of 'The Musical Language.'

"A Committee of the Academy . . . reported, that after 'causing several experiments to be made and repeated in their presence,' they had 'come to the conclusion, that the author had perfectly attained the end he had in view, namely, that of creating a *real musical language*'; and that a system of telegraphic communication might be established by means of this language, and the aid of musical instruments, far superior to any hitherto in use, inasmuch as it would enable men to correspond instantaneously with each other at great distances, not only during the most profound darkness, but under circumstances

* The *Mechanics' Magazine*, London, vol. xxiii, July 4, 1835.

in which even in open day, no communication by visible signals could possibly be carried on.

"The invention was afterward referred . . . to a Military Commission . . . which made an equally favourable Report upon it. . . .

"M. Sudre's invention was next investigated by a Commission of Naval Officers, who reported it to be their unanimous opinion, that 'it would be a powerful auxiliary to the means at present used in the navy, and ought to be immediately adopted.' From a series of experiments . . . it appeared that 'it only required two minutes to transmit by means of the "Musical Language," from one point to another, distant 9,000 feet, three orders taken from the book of signals.'

"The system was finally submitted to a Committee of all the five Academies of the French Institute . . . and from the Report of this Committee . . . the following are extracts:

"The Committee are of opinion, that the "Musical Language" . . . 1st. Furnishes a means of communication capable of expressing all our ideas. 2nd. Either by sounds or by (written)* characters. 3rd. At short or long distances. 4th. Openly or secretly (that is, by using combinations of the signs, known only to the corresponding parties.) And 5th. That this system of sounds is not liable, like spoken languages, to change with time, but is essentially unalterable.

"The TELEGRAPH † can only be used at certain stations, upon heights, when everything has been foreseen, tried, regulated beforehand and at leisure. It is impossible to make use of it without preparation. . . .

"But the TELEPHONY can be put in practice on land in almost every place, by day or by night, without any change in the method, and even more easily by night, on account of the profound silence which then pervades the earth.

"This generality of application acquires additional value, when it is considered that the instrument is of the most portable description; that it is always *at hand in those very circumstances when the greatest benefits would be derived from its use*; and that the persons who make use of it for other purposes would speedily learn to apply it to the one before us. . . .

"The particular 'instrument' referred to in the last extract is the French horn or trumpet, which may be heard at a distance of three miles, and is that which would most probably be employed in all cases of distant communication; but of course any instrument capable of expressing the different musical signs may be made the organ of this new language.

"M. Sudre is now in London for the purpose of unfolding all the

* This is in parentheses in the text of the article in the *Mechanics' Magazine*.

† Evidently the Semaphore.

details of his system to the English public; for it would seem that notwithstanding the various strong reports which we have cited in his favour, he has met with but poor encouragement from the Government of his own country. . . ."

3.—William Fothergill Cooke, Esq., in his book, *The Electric Telegraph*,* gives a letter of October 26, 1840, from C. Wheatstone, which says, in part:

"The subject of telegraphic communication has for a long series of years engrossed my thoughts. When I made, in 1823, my important discovery, that sounds of all kinds might be transmitted perfectly and powerfully through solid wires, and reproduced in distant places, I thought that I had the most efficient and economical means of establishing a telegraphic (or rather a telephonic) communication between two remote points that could be thought of."

4.—The following article, entitled "The Telephone," is quoted from Timbs's *Year Book* of 1845 † :

"Captain John Taylor has invented this powerful instrument for conveying signals during foggy weather, by sounds produced by means of compressed air forced through trumpets, audible at six miles distance. The four notes are played by opening the valves of the recipient, and the intensity of sound is proportioned to the compression of the internal air. The small-sized telephone instrument, which is portable, was tried on the river, and the signal notes were distinctly heard four miles off. The instrument is engraved in a late number of the *Illustrated London News*."

5.—From a manuscript letter of Alexander Graham Bell of April 9, 1888, is a reference to an article in Dingler's *Journal* of 1846 ‡ :

"The Telephone, an Acoustic Means of Communication on Railroads, etc., by Dr. Romershausen. Already in the year 1838 I proposed, under the name of 'Telephone,' a means of speech-communication, very easily practicable and adapted to immediate and comprehensive communications through the use of the far-reaching transmission of sound in narrow tubes."

6.—The following quotation is from Chambers's *Edinburgh Journal* for June 30, 1849,** under the heading "Gossip from London":

"While on the subject of gutta-percha, a few words may very well be given to Mr. Whishaw's inventions: among these are speaking-

* *The Electric Telegraph*, William Fothergill Cooke, Esq., London, W. H. Smith and Son, Strand, 1857, p. 114.

† Timbs's *Year Book of Facts*, London, 1845, p. 55.

‡ Dingler's *Polytechnisches Journal*, Stuttgart, 1846, p. 413.

** Chambers's *Edinburgh Journal*, vol. xi, June 30, 1849, p. 408.

tubes, to supersede bells in private houses or offices. So extraordinary are the conducting powers of this new product, that a whisper can be conveyed to long distances; and it is obvious that much trouble will be saved by a person being able to state his wants without the preliminary delay of a bell-summons. . . .

"But we are, it seems, to be able to speak to a distance without any connecting tube at all; across the inner quadrangle of a building, for instance, by means of large concave gutta-percha reflectors, fixed, one opposite to the other, on each side of the court, at an upper window, if required, each having a short tube attached, through which the message is spoken. By experiment, the inventor has ascertained that a whisper can be heard at a distance of forty feet; and he anticipates hearing a loud-spoken tone from a quarter of a mile. Such an instrument has long been desiderated on railways during repairs, so as to avoid the delay which now occurs in sending a messenger from one gang of workmen to another. In this case each reflector would be mounted on a stand similar to that of a theodolite; and thus the portable *telephone* would be available where the *telegraph*, as at present arranged, does not admit of application. The instrument might be so fixed at each end of a tunnel, that the attendants at either extremity could communicate without leaving their boxes."

7.—Timbs's *Year Book of Facts* for 1854* contains the following article under the heading "New Telephone":

"A very curious System of Telephony for the transmission of language at great distances, by means of musical sounds, has been invented by M. Sudre, at Paris. The plan consists in making use of three notes placed at given intervals; and which, combined, or repeated according to certain rules, are capable of rendering the most complicated sentences. Thus, one of the company writes a few lines, and on M. Sudre reading them, he strikes his three notes alternately, according to his method, when a third person, without any previous knowledge of the writing, repeats the words merely from hearing the notes. The system has been, it is understood, tried on a very extensive scale, to test its applicability to naval and military purposes, and is stated fully to justify the high encomiums the French Institute and other scientific bodies have bestowed on it."

8.—The following quotation is from Tegg's *Posts and Telegraphs*,† in the portion of the book dealing with the Telephone:

* Timbs's *Year Book of Facts*, London, 1854, p. 130.

† *Posts and Telegraphs*, Tegg, London, 1878, p. 290.

"On the 10th of May, 1855, a similar exhibition * . . . took place before Her Majesty the Queen, at the Polytechnic Institution, of which the only account that has been reproduced is that given by Mr. C. K. Salaman, in a letter to the 'Choir':

"1. Lecture by J. H. Pepper, Esq., on Professor Wheatstone's experiments on the transmission of musical sounds to distant places, illustrated by a Telephone concert, in which sounds of various instruments pass inaudible through an intermediate hall, and are reproduced in the lecture room, unchanged in their qualities and intensities.'"

9.—In *Cosmos*, 1858,† occurs a reference to a system of acoustic telegraphy using signals formed of long and short sounds and termed "téléphonie-électrique." The article quotes at length from a Belgian publication. It is entitled "Faits de science étrangère." The apparatus is not described, but the paragraph containing the reference is as follows:

"Le système est nouveau: 1° par la grande simplicité du mécanisme; 2° par la facilité, tant de transmettre que de recevoir les signaux; 3° en ce que, au lieu de faire les transmissions lettre par lettre, comme dans les systèmes suivis jusqu'à ce jour, on transmet des mots, des phrases entières; enfin, 4° il est encore nouveau, en ce que, au lieu de s'adresser aux yeux, il parle à l'oreille avec des sons, au choix du transmetteur, brefs ou coupés, longs ou soutenus; c'est cette dernière différence qui a fait baptiser le système dont il s'agit, du nom de 'Téléphonie-électrique,' c'est encore de cette même différence que découlent tous les avantages pratiques de cette ingénieuse application du fluide galvanique."

10.—The word "telephone" occurs in Sir Charles Wheatstone's British patent No. 2,462, October 10, 1860, which is entitled "Improvements in Electro-Magnetic Telegraphs." The following text is quoted from that patent:

"The sixth improvement consists in the employment of musical pipes, or free tongues (such as employed in the concertina, harmonium, & other similar instruments), acted upon by wind for the purpose of communicating intelligence by means of audible instead of visible signs. I prefer to employ pipes or tongues producing very high sounds, since they require a much less quantity of wind than lower sounds. The passage between the reservoir of air and the pipe or tongue is closed by a valve, which when acted upon by an electro-

* This refers to an exhibition given on November 26, 1840, by Sir Charles Wheatstone, before the Royal Society, in which he transmitted the ticking of a clock, over a wire, from one room to another.

† *Cosmos*, Paris, 1858, vol. xii, p. 457.

magnet opens and allows the passage of the wind to the pipe or tongue. . . .

"With this apparatus long and short sounds may be made to follow each other in the successions constituting the letters of Morse's telegraph. Two such pipes or tongues producing different notes connected with the same or separate reservoirs, the valve of one acted upon when the current proceeds in one direction, and the valve of the other when the current proceeds in the opposite direction constitutes a telephone, of which the alphabet may correspond with that of the usual single needle telegraph."

11.—In *Jahresbericht des Physikalischen Vereins zu Frankfurt am Main, für das Rechnungs Jahr 1860-1861*, Philipp Reis said, "I give to my instrument the name 'telephone.'" And to Reis's apparatus the name "telephone" was applied almost exclusively from that time until Bell invented the electric speaking telephone.

12.—The following quotation is from an article by Professor Edwin J. Houston, entitled "On the Transmission of the Sound of the Human Voice by Rods of English Deal," from the *Journal of the Franklin Institute*, 1871 *:

"An interesting modification of Wheatstone's celebrated experiment of the Telephonic Concert was recently tried at the Central High School of Philadelphia. A rod of English Deal, about twenty feet in length and three-quarters of an inch thick was let down through a platform into a room below. Insulation from the platform and the ceiling of the lower room was obtained by enclosing the rod with small sections of thick rubber hose, against the lower end of the rod the sounding box of a small tuning fork was placed. On speaking or singing into the open end of this, the sounds were transmitted by the rod to the room above, the volume of the sound being increased by placing a guitar on the upper end of the rod."

13.—An additional reference to the use of the word "telephone" by Reis, and an interesting description of his instrument, is contained in *Tegg's Posts and Telegraphs* † :

"In 1861 Professor Reis, of Friedrichsdorf, near Homburg, Germany, succeeded in constructing an apparatus, the distinctive feature of which was a stretched membrane vibrating to a particular pitch or note. By his instrument a melody could be reproduced at a distance with distinctness, but the sounds were low, and they had besides a tin-trumpet quality. Of this apparatus Professor Barrett said, in a lecture recently delivered: 'The first Telephone was of a most primitive nature. The originating instrument was a bung of a beer barrel

* *Journal of the Franklin Institute*, Philadelphia, 1871, Third Series, vol. lxii, p. 8.

† *Posts and Telegraphs*, Tegg, London, 1878, p. 292.

hollowed out, and the cone formed in this way was closed with the skin of a German sausage, which did service as a membrane. To this was fixed with a drop of sealing-wax a little strip of platinum, representing the hammer of the ear, and which "made" or "broke" the electric circuit, precisely as in the instruments * of a later date. The receiving instrument was a knitting-needle surrounded with a coil of wire and placed on a violin to serve as a sounding-board.' " †

14.—Alexander Graham Bell, in his deposition of 1892,⁷ said:

"I do not think that at the time I filed that application and obtained that patent ⁸ there was any inaccuracy or impropriety in entitling my invention 'Improvements in Telegraphy.' At that time an apparatus capable of the electrical transmission and reproduction of articulate speech was a new thing, and there was no specific name by which to designate it. The word 'telephone' had another signification at that date, and was applied to an apparatus of entirely different character. I think it would have been appropriate, at that time, to entitle my invention either 'Improvements in Telephony,' or 'Improvements in Telegraphy.' I preferred the latter title. . . . Indeed, it was not until a long time after the issue of my patent of March 7, 1876, that the word 'telephony' became a recognized term in the art. For example, my provisional specification, filed in the British Patent Office on the ninth day of December, 1876, was entitled by me 'Improvements in Electric Telephony and Telephonic Apparatus'; but the Patent Office would not accept the title without a definition of the new term 'telephony,' employed. This was accordingly defined by the British Patent Office, or by my solicitors abroad, in a parenthetical clause, as 'Transmitting or Causing Sounds for Telegraphing Messages.'

"Again, as late as 1877, the United States Patent Office classified my application filed January 15, 1877, which resulted in the issue of patent No. 186,787, January 30, 1877, as an 'Improvement in Electric Telegraphy,' although I had myself entitled the invention in the specification itself as 'Improvements in Electric Telephony.'"

15.—Bell said, in his letter of April 9, 1888 (already referred to):

"I christened my apparatus 'The Electric Speaking-Telephone,' but the world has abbreviated it to 'Telephone' alone."

* Reis's instruments.

† The language attributed to Professor Barrett was evidently taken from his paper, "On the Electric Telephone," read November 19, 1877, before the Royal Dublin Society. Professor Barrett states in this paper that the information is from a letter of Dr. Messel, a former pupil of Reis and an eye-witness of his early experiments.

⁷ Ref. (2) p. 179, *et seq.*

⁸ U. S. Patent No. 174,465.

APPENDIX C NUMERICAL LIST OF UNITED STATES PATENTS CITED

<i>Number</i>	<i>Date of Issue</i>	<i>Patentee</i>	<i>Feature Covered by Patent</i>	<i>Page Reference</i>
161,739	Apr. 6, 1875	Bell, A. G.	Harmonic Telegraph System	50
174,465	Mar. 7, 1876	Bell, A. G.	Fundamental Principle of the Electric Speaking Telephone	14, 26, 50, 51, 52, 61
178,399	June 6, 1876	Bell, A. G.	Harmonic Telegraph Receiver	50
186,787	Jan. 30, 1877	Bell, A. G.	Fundamental Telephone Receiver Patent, Covering a Receiver with a Permanent Magnet and an Iron or Steel Plate Diaphragm	50, 52
199,007	Jan. 8, 1878	Watson, T. A.	"Buzzer" for Substation Signaling	177
199,141	Jan. 15, 1878	Berliner, Emile	Use of Induction Coil with Transmitter	180
203,013	Apr. 30, 1878	Edison, T. A.	Use of Induction Coil with Transmitter	180
203,016	Apr. 30, 1878	Edison, T. A.	Transmitter Employing Compressed Lamp Black	79
210,886	Dec. 17, 1878	Watson, T. A.	Fundamental Patent on the Polarized Substation Bell	177
212,792	Mar. 4, 1879	Dickerson, E. N., Jr.	Selective Signaling Arrangement Employing an Electro-magnetic Step-by-Step Device	185
215,837	May 27, 1879	Roosevelt, H. L.	Fundamental Patent on the Automatic Hook-Switch	178
218,153	Aug. 5, 1879	Anders, G. L.	Selective Signaling System Employing Polarized Bells	184
219,059	Sept. 2, 1879	Anders, G. L.	Selective Signaling Arrangement Employing an Electro-magnetic Ratchet and Pawl	185
219,188	Sept. 2, 1879	Vail, T. N.	Selective Signaling System Employing a Special Circuit Arrangement of Conductor Combinations	186
221,512	Nov. 11, 1879	Buell, C. E.	Selective Signaling Arrangement Employing Currents of Different Strength	184
222,458	Dec. 9, 1879	Connolly, M. D., Connolly, T. A., and McTighe, T. J.	Automatic Telephone System	166

<i>Number</i>	<i>Date of Issue</i>	<i>Patentee</i>	<i>Feature Covered by Patent</i>	<i>Page Reference</i>
223,469	Jan. 13, 1880	Bliss, G. H.	Selective Signaling Arrangement Employing Clockwork Bells	185
224,855	Feb. 24, 1880	Vail, T. N.	Selective Signaling System Employing a Special Circuit Arrangement of Conductor Combinations	186
228,047	May 25, 1880	Eaton, C. S.	Selective Signaling Arrangement Employing Clockwork Bells	185
230,530	July 27, 1880	Curtis, C. G. and Crocker, F. B.	Selective Signaling Arrangement Employing an Electromagnetic Step-by-Step Device	185
232,093	Sept. 7, 1880	Warner, E. P.	Annunciator Drop	157
232,442	Sept. 21, 1880	Blake, Francis	Selective Signaling Arrangement Employing Clockwork Bells	185
235,199	Dec. 7, 1880	Bell, A. G.	Photophone	45
242,408	May 31, 1881	Anders, G. L. and Vail, T. N.	Selective Signaling Arrangement Employing Currents of Different Strength and Direction	184
244,426	July 19, 1881	Bell, A. G.	Twisted-Pair Metallic Circuit	92, 93
246,512	Aug. 30, 1881	Hunnings, Henry	Use of Finely Divided Carbon as the Variable Resistance Element in a Transmitter	79
250,126 }				
250,127 }				
250,128 }				
250,129 }				
250,250	Nov. 29, 1881	Hunnings, Henry	Blake Transmitter, Employing One Carbon and One Platinum Electrode, Supported on Springs	79
251,097	Dec. 20, 1881	Currier, J. B.	Use of Any Finely Divided Conducting Material as the Variable Resistance Element in a Transmitter	81
252,576	Jan. 17, 1882	Firman, L. B.	Harmonic Signaling System	186
262,252	Aug. 8, 1882	Southworth, H. W.	Fundamental Principle of the Multiple Switchboard	155
			Selective Signaling Arrangement Employing Galvanometers	186

<i>Number</i>	<i>Date of Issue</i>	<i>Patentee</i>	<i>Feature Covered by Patent</i>	<i>Page Reference</i>
266,287	Oct. 24, 1882	Haskins, C. C. and Wilson, C. H.	First Electrical Busy Test for Multiple Switchboard	156
268,554	Dec. 5, 1882	Shaw, Frank	Head-Band Receiver for Operators	158
270,522	Jan. 9, 1883	Watson, T. A.	Improved Form of Automatic Hook-Switch	179
281,741	July 24, 1883	Warner, J. C.	Spring-Jack	156
287,288	Oct. 23, 1883	Jacob, Frank	Phantom Circuit Arrangement Employing Balanced Resistances	189
293,198	Feb. 5, 1884	Scribner, C. E.	Jack-Knife Switch	152
303,714	Aug. 19, 1884	Eldred, H. H.	Clearing-Out Drop	153
304,667	Sept. 2, 1884	Richards, W. L.	Operator's Head Receiver	158
308,315	Nov. 18, 1884	Kellogg, M. G.	Busy Test for Multiple Switchboard	156
322,214	July 14, 1885	Vail, T. N.	Protector	182
330,060	Nov. 10, 1885	Scribner, C. E.	"Click" Busy Test for Multiple Switchboard	158
330,067	Nov. 10, 1885	Seely, J. A.	Convenient and Uniform Grouping in Multiple Switchboard of the Annunciators and Their Corresponding Answering Jacks	159
346,708	Aug. 3, 1886	Bell, C. A.	Common Battery Switchboard Arrangement	163
348,512	Aug. 31, 1886	Carty, J. J.	Phantom Circuit Arrangement Employing Repeating Coils	191
360,570	Apr. 5, 1887	Farnham, I. H.	Protector	181
377,073	Jan. 31, 1888	Hibbard, A. S.	Protector	182
392,775	Nov. 13, 1888	Barrett, J. A.	Transposition System	98
395,137	Dec. 25, 1888	Hayes, H. V.	Common Battery Switchboard Arrangement	163
399,377	Mar. 12, 1889	Carty, J. J.	Phantom Circuit Transposition System	193
400,969	Apr. 9, 1889	Thayer, H. B.	Spring-Jack	160
406,567	July 9, 1889	Edison, T. A.	Use of Granules of Carbonized Hard Coal as the Variable Resistance Element in a Transmitter	81
431,962	July 8, 1890	Barton, E. M.	Intermediate Distributing Frame	160

<i>Number</i>	<i>Date of Issue</i>	<i>Patentee</i>	<i>Feature Covered by Patent</i>	<i>Page Reference</i>
438,788	Oct. 21, 1890	White, A. C.	Lightning Arrester	183
447,918	Mar. 10, 1891	Strowger, A. B.	Automatic Telephone System	166
449,106	Mar. 31, 1891	Carty, J. J.	Bridging Substation Bell	180
458,753	Sept. 1, 1891	Hayes, H. V. and White, A. C.	Protector	182
463,569	Nov. 17, 1891	Berliner, Emile	Variable Pressure Contact Transmitter Employing Metallic Electrodes	78, 82, 83, 94
474,230	May 3, 1892	Edison, T. A.	Variable Pressure Contact Transmitter Employing Metal Disk and Plumbago Film Electrodes	78
474,231	May 3, 1892	Edison, T. A.	Variable Pressure Contact Transmitter Employing a Series of Plumbago Cylinders	78, 84
474,323	May 3, 1892	Hayes, H. V.	Repeating Coil System of Battery Supply for Common Battery Switchboard	164
485,311	Nov. 1, 1892	White, A. C.	Solid Back Transmitter	82
503,099	Aug. 8, 1893	Scribner, C. E.	Bridging Line Circuit for Multiple Switchboard	160
507,424	Oct. 24, 1893	Ford, W. S. and Lenfest, B. A.	Distributing Frame	161
507,568	Oct. 31, 1893	Stone, J. S.	Bridged Impedance Cord Circuit for Common Battery Switchboard	165, 166
511,276	Dec. 19, 1893	Pickernell, F. A.	Selective Signaling System for Divided Two-Party Ringing Protector	187
550,638	Dec. 3, 1895	McCulloch, A. H.	Harmonic Signaling System Employing a Battery and Interrupter Arrangement	182
550,982	Dec. 10, 1895	Lighthipe, J. A.	Four-Party Selective Signaling System Employing Oppositely Biased Polarized Bells	186
555,725	Mar. 3, 1896	Hibbard, A. S.	Bridged Impedance Cord Circuit for Common Battery Switchboard	187
559,616	May 5, 1896	Scribner, C. E.	Bridged Impedance Cord Circuit for Common Battery Switchboard	165, 166

<i>Number</i>	<i>Date of Issue</i>	<i>Patentee</i>	<i>Feature Covered by Patent</i>	<i>Page Reference</i>
563,250	July 7, 1896	Bell, O. A.	Electrically Restored Drops	160
582,107	May 4, 1897	Whittemore, G. W., Barrett, J. A. and Craft, W. M.	Four-Party Selective Signaling System	188
644,647	Mar. 6, 1900	Thompson, G. K. and Robes, E. C.	Four-Party Selective Signaling Arrangement	188
652,230 } 652,231 }	June 19, 1900	Pupin, M. I.	Fundamental Patents on the Art of Loading	137
763,970	July 5, 1904	Drake, T. C.	Four-Party Selective Signaling Arrangement Employing an Alternating Current Generator in Series with Plus and Minus Batteries	188
863,969	Aug. 20, 1907	Dieselhorst, William and Martin, A. W.	Method of Constructing Quaddled Cables	195
980,921	Jan. 10, 1911	Campbell, G. A. and Shaw, Thomas	} Fundamental Patents on the Loading of Phantom Circuits...	195
981,015 1,064,433	Jan. 10, 1911 June 10, 1913	Shaw, Thomas Blackwell, O. B. and Anderegg, G. A.		
1,124,249	Jan. 12, 1915	Anderegg, G. A.	Method of Reducing Disturbances in Quaddled Cables	195
1,167,677	Jan. 11, 1916	Campbell, G. A., Blackwell, O. B. and Colpitts, E. H.	Method of Assembling Wires to Form a Cable Having Low Electrostatic Capacity Unbalances	195
			Capacity Unbalance Testing for Quaddled Cables	195
1,271,824	July 9, 1918	Anderegg, G. A. and Mougey, W. E.	Basic Patent Covering a Quad Having Quad Twists Shorter Than One of the Pair Twists	195

APPENDIX D

SOURCES OF INFORMATION CONSULTED

"A man will turn over half a library to make one book."—Dr. Johnson.

- (1) *Encyclopedia Americana*, biographical article, "Alexander Graham Bell."
- (2) Circuit Court of the United States, District of Massachusetts. No. 2356A. In Equity. United States of America, Complainant, *v.* American Bell Telephone Company and Alexander Graham Bell, Defendants. Deposition of Alexander Graham Bell and cross-examination by Charles S. Whitman, Esq., of Counsel for Complainant. Printed by The American Bell Telephone Company, 1908, and known, colloquially, as the "Red Book."
- (3) Proceedings of the Telephone Pioneers of America, October 17, 1913. "The Birth and Babyhood of the Telephone," an address by Thomas A. Watson.
- (4) Circuit Court of the United States, District of Massachusetts. No. 1424. American Bell Telephone Company et al. *v.* Albert Spencer et al. Opinion of the Court, June 27, 1881. Lowell, J. (8 Federal Reporter 509).
- (5) *The Bell System Technical Journal*, vol. v, No. 1, January, 1926. "Joseph Henry—The American Pioneer in Electrical Communication," by Bancroft Gherardi and Robert W. King.
- (6) *Transactions of the American Institute of Electrical Engineers*, vol. xxxiv, part 1, 1915. "How Bell Invented the Telephone," by Thomas A. Watson.
- (7) *Exploring Life. The Autobiography of Thomas A. Watson*, D. Appleton and Company, New York, London, 1926.
- (8) *Bell Telephone Quarterly*, vol. ii, No. 4, October, 1923, "Two Founders of the Bell System," by William Chauncy Langdon, Historical Librarian, American Telephone and Telegraph Company.
- (9) *Proceedings of the American Academy of Arts and Sciences*, vol. xii, "Researches in Telephony," May 10, 1876, by Alexander Graham Bell.
- (10) *Nature*, London, England, September 14, 1876.
- (11) *Bell Telephone Quarterly*, vol. v, No. 2, April, 1926. "Episodes in Early Telephone History"—extracts from an address by John J. Carty, Vice President, American Telephone and Telegraph Com-

- pany, before the Chamber of Commerce of Boston, Massachusetts, March 11, 1926.
- (12) *Scientific American*, September 9, 1876, "The Human Voice Transmitted by Telegraph."
 - (13) *Boston Daily Advertiser*, October 19, 1876.
 - (14) *Boston Post*, November 27, 1876.
 - (15) *Boston Globe*, February 13, 1877.
 - (16) *The History of Bell's Telephone*, edited by Kate Field, London; Bradbury, Agnew & Company, 8, 9, 10, Bouverie Street, E. C., 1878.
 - (17) Certified copy, record of meeting of the Essex Institute, Salem, Massachusetts, U. S. A., February 19, 1877, in American Telephone Historical Collection.
 - (18) *Boston Daily Globe*, April 5, 1877.
 - (19) *The Telephone and Telephone Exchanges—Their Invention and Development*, by J. E. Kingsbury; Longmans, Green, and Co., London and New York, 1915.
 - (20) *Bell Telephone Quarterly*, vol. i, No. 3, October, 1922. "Dr. Bell's Appreciation of the Telephone Service," a copy of a letter of August 24, 1922, from Mabel G. Bell to John J. Carty.
 - (21) *Bell Telephone Quarterly*, vol. ii, No. 3, July, 1923, "The Early Corporate Development of the Telephone," by William Chauncy Langdon, Historical Librarian, American Telephone and Telegraph Company.
 - (22) Circuit Court of the United States, Eastern District of Louisiana. In Equity. American Bell Telephone Company et al. *v.* National Improved Telephone Company et al. Opinion of Pardee, Circuit Judge, and Billings, District Judge, May 31, 1886 (27 Federal Reporter 663).
 - (23) Supreme Court of the United States, October term, 1887; Nos. 10, 361, 362, 709, 770, 771. (The Telephone Appeals.) Opinion of March 19, 1888, Mr. Chief Justice Waite. (126 U. S.)
 - (24) Circuit Court of the United States, Southern District of New York. American Bell Telephone Company et al. *v.* The Globe Telephone Company et al. (The Meucci Case.) Opinion of Judge Wallace, July 19, 1887. (31 Federal Reporter 729.)
 - (25) Circuit Court of the United States, Southern District of New York. American Bell Telephone Company et al. *v.* The People's Telephone Company et al. (The Drawbaugh Case.) Opinion of Judge Wallace, December 1, 1884. (22 Federal Reporter 309.)
 - (26) Circuit Court of the United States, District of Massachusetts. In Equity. United States of America, Complainant, *v.* American Bell Telephone Company and Emile Berliner, Defendants. (The Berliner Case.) Vol. I, Deposition of Berliner, p. 308 (1893).
 - (27) Circuit Court of the United States, District of Massachusetts. In Equity. American Bell Telephone Company, Complainant, *v.*

- Century Telephone Company et al., Defendants. Vol I. Deposition of Charles R. Cross, p. 91, 93 (1895).
- (28) The *Telegraphic Journal and Electrical Review* (London), August 15, 1878, p. 340.
 - (29) *Ibid*, July 1, 1878, p. 274.
 - (30) Circuit Court of the United States, District of Massachusetts. *United States v. American Bell Telephone Company et al.* (The Berliner Case.) Opinion of December 18, 1894; Carpenter, J. (65 Federal Reporter 86.)
 - (31) U. S. Circuit Court of Appeals, First Circuit. *American Bell Telephone Company et al. v. United States.* (The Berliner Case.) Opinion of May 18, 1895; Putnam, Circuit Judge. (68 Federal Reporter 542.)
 - (32) Supreme Court of the United States. *United States v. American Bell Telephone Company.* (The Berliner Case.) Opinion of May 10, 1897; Mr. Justice Brewer. (167 U. S. 224.)
 - (33) U. S. Circuit Court of Appeals, First Circuit. No. 401. *American Bell Telephone Company v. National Telephone Manufacturing Company et al.* Opinion of January 16, 1903; Colt, Circuit Judge. (119 Federal Reporter 893.)
 - (34) Information as to early telegraph lines sent to the author by P. G. Burton, Esq., of Washington, D. C., who obtained it from the Congressional Library, the files of the Smithsonian Institution, and documents in the U. S. Treasury Department.
 - (35) Proceedings of the National Telephone Exchange Association, 1880.
 - (36) *Ibid.*, 1881.
 - (37) *Ibid.*, 1882.
 - (38) *Ibid.*, 1883.
 - (39) *Ibid.*, 1884.
 - (40) *Ibid.*, 1885.
 - (41) *Ibid.*, 1886.
 - (42) *Ibid.*, 1887.
 - (43) *Ibid.*, 1888.
 - (44) Testimony of John J. Carty before the Public Service Commission, State of New York, at Albany, New York, March 15, 1922.
 - (45) In the matter of Interference between the applications, respectively, of A. G. Bell and David Brooks, for patents for Telephone Circuit. Deposition of A. G. Bell before the Honorable Commissioner of Patents. Subscribed and sworn to April 24, 1879.
 - (46) U. S. Patent Office, No. 6285, November 30, 1880. Before the Examiners-in-Chief on Appeal. In the matter of the Interference between the application of Alexander G. Bell, filed December 20, 1878, and the application of David Brooks, filed March 4, 1878.
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